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How to Communicate Chemical Knowledge? – A Qualification Course for PhD Students of Chemistry

Abstract

Scientists must not only undertake research, but also convey their knowledge to different people. For this reason, the professionalisation of doctoral candidates requires them to be trained in skills needed for teaching specific subjects. The project described here focuses on the training of skills needed by PhD students for communicating chemical knowledge. In the study, the typical teaching tasks undertaken by chemists were first drawn up. Also, a model of the teaching skills needed by scientists was developed and then adapted specifically to chemistry. This model serves as a basis for designing a course qualifying participants to transfer chemical knowledge. This was developed, tested and evaluated in line with the design-based research approach.

Keywords

Doctoral education in chemistry, professionalisation of PhD students, model of teaching skills, model-based qualification course, communication/ presentation skills

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1 Introduction

As a result of the Bologna Declaration of 1999, the doctoral education is no longer considered to be simply the achievement of a qualification in the student's subject. Rather, it is seen as a broadly-based training phase in which a wide range of competences for a professional career should be acquired (SZCZYRBA & WERGEN, 2009). In 2015, 83% of chemistry Masters questioned embarked on a doctoral degree course in chemistry (GDCH, 2016). This means that chemistry represents the field in which most doctoral degrees are taken. PhD in chemistry is characterised by a strong focus on specialist training. The problems which result from such subject-related specialisation can be described using a quotation from Georg Christoph Lichtenberg: *"Anyone who can only do chemistry cannot even do that properly"* (KRULL, 2003, p. 227, translated from German (tfG)). One of the things a chemist has to do at work is to report knowledge (AKESSON et al., n.d.):

> *"[Because] in the end, of course, [chemists] will very probably not be standing in the lab and mixing their potions, but will be spending a lot of their time communicating."* (06I, 31:08 min., tfG)

So far, doctoral students have not been adequately prepared for these tasks, as there will have been no educational training during their studies (e.g. Westfälische Wilhelms-Universität Münster, 2013). For this reason, a subject-related university course has been developed jointly by the Institute of the Didactics of Chemistry and the Department of Chemistry at Münster University which prepares students for their later careers. This is incorporated in the Integrated Research Training Group of the Collaborative Research Centre (SFB) 858. This Research Training Group provides a framework for the individual research done by doctoral students in the form of a structured PhD course programme (MÜNSTER, 2010). This is an attempt – such as is being undertaken at many German universities – to structure the doctoral education and create a basis for professional competence.

Professional competence of chemists

The Bologna requirements ask the question of what qualifications are needed for professional activity. These qualifications need to be geared to the relevant subject, as well as being specific to the career later embarked on.

The profession of a chemist is one which has many fields of activity (GDCH, 2012; KÖNEKAMP, 2007). The classic idea of the profession has given way to a pragmatic one which is similar to the term “expert”. TERHART (2011, p. 215) describes the term “professional” – upon which this article is based – as follows:

> *“Difficult, complex and risky tasks and problems can only be mastered on the basis of knowledge gained in high-quality training and careful professional socialisation, as well as appropriate attitudes, abilities and skills. The more competently people perform these tasks, the more professional they are.”* (tfG)

Currently, there is no model which describes professional competences required from a chemist. By observing a chemist’s field of activity, various competences can be assumed which a chemist needs to perform his job in a professional manner. This article is focused on the field of communicating knowledge. By this, we understand the transfer of chemical understanding to at least one person. This person can be distinguished from the person providing the transfer on the basis of his or her (previous) knowledge, social role and interest. The process of information transfer can take place in a variety of contexts, e.g. a lecture or a discussion. By content knowledge in chemistry we understand the phenomena, terms, models, processes and concepts used in chemistry. The objective of any such transfer is always an increase in the recipient’s knowledge.

It is clear that the professional knowledge possessed by a chemist in this specific area is similar to that of a teacher (GROßEBRAHM, 2013; URBAN & MEISTER, 2010). It cannot, however, be identical in this area as the tasks, aims and self-perception of the two professions are different. While the professional competence of a teacher, and his professional knowledge, has been described in several models, this has not yet been done for chemists (cf., for example GRAMZOW, RIESE &

REINHOLD, 2013; RIESE, 2009). Something which needs to be clarified is which knowledge and skills chemists need as a basis for teaching competence, and how this can be incorporated in a model describing professional competence.

This article presents both a model of the teaching skills that chemists need and a qualification course in chemistry for PhD students. As far as the methodology is concerned, the project follows the design-based research (DBR) approach.

2 Development of a qualification course based on design-based research

DBR was developed *"as a way to carry out formative research to test and refine educational designs based on theoretical principles derived from prior research"* (COLLINS, JOSEPH & BIELACZYC, 2004, p. 18). It always has two aims: on the one hand, the development of an intervention in a real educational context (REINMANN, 2005); and, on the other, the creation of theories which describe this intervention and its effect (COLLECTIVE, 2003). Other characteristics of the DBR approach are, according to ANDERSON & SHATTUCK (2012), the collaborative partnership between researchers and practitioners, an orientation towards benefit and the use of different methods of analysis and evaluation ("mixed methods"). The DBR approach is also characterised by a cyclical process. In this, the intervention is revised step by step and adapted to the teaching situation (REINMANN, 2005). The DBR is to be understood as a research framework which needs to be adjusted to every project (REINMANN, 2005). Figure 1 – with reference to ROTT & MAROHN (2016) – shows the structure of a model of an idealised sequence of the project in question.

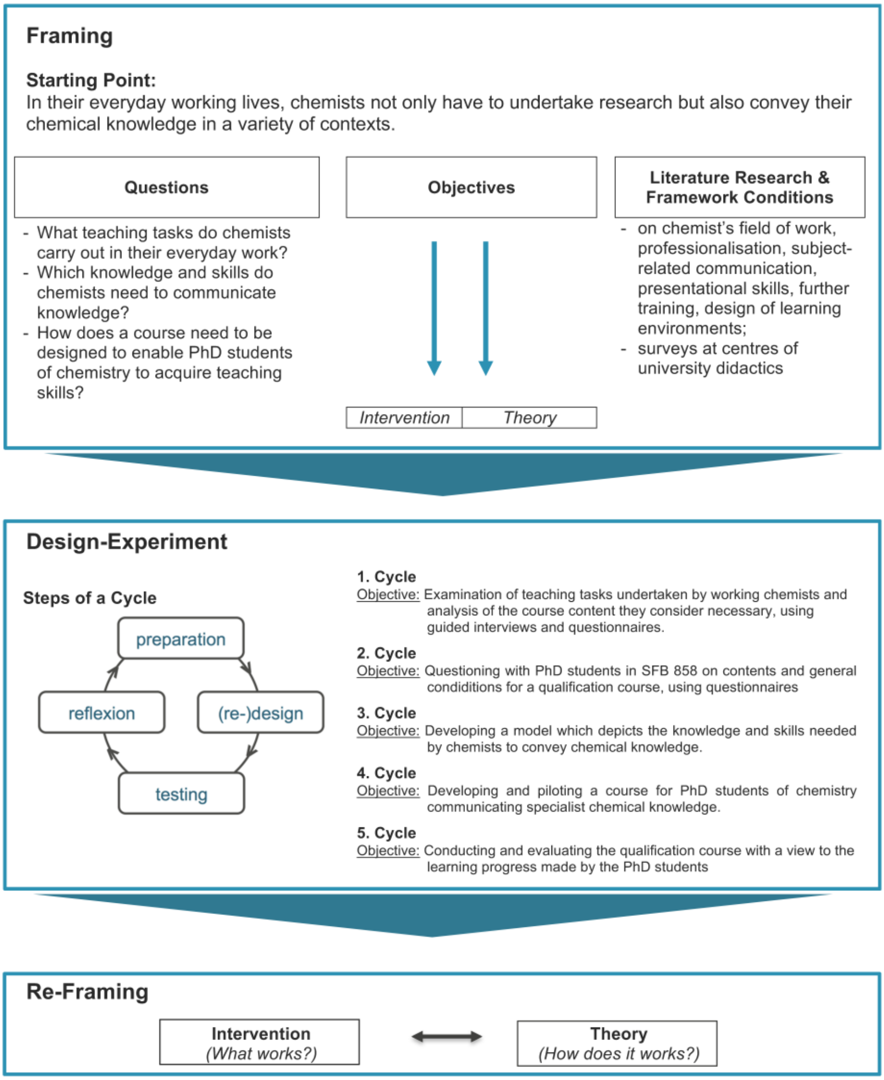


Fig. 1: Sequence of the project as part of DBR.
Depiction based on ROTT & MAROHN (2016).

The approach is characterised by three phases (VAN DEN AKKER, GRAVEMEIJER, MCKENNEY & NIEVEEN, 2006):

1. **Framing**: This is the phase in which the project is prepared. Proceeding from a problem encountered in practice, a question is formulated. Moreover, the framework is clarified and an analysis of the problem is undertaken by means of literature research.

2. **Design experiment:** In a cyclical process a solution is sought for the problem taken from practice. Each cycle is divided into the following four steps:
   <u>Preparation</u>: In this step, an aim is formulated and the framework is clarified.
   <u>(Re-)Design</u>: A design is developed for reaching the aim.
   <u>Testing</u>: The design developed is tested in practice.
   <u>Reflexion</u>: The data gathered during the testing are evaluated with a view to the aim.

3. **Re-Framing**: All the cycles are reviewed in order to be able to answer the question formulated for the project. A check is also made to see whether a successful intervention was devised and whether any theories can be derived.

2.1 Framing

As a result of the problem(s) shown (cf. Chapter 1), the research project deals with the challenge of developing a course for training teaching skills in PhD students of chemistry to be prepared for further job challenges in this field. For this purpose, the following questions are considered with a view to a needs-based design:

– What teaching tasks do chemists carry out in their everyday work?
– Which knowledge and skills do chemists need to communicate knowledge?

– How does a course need to be designed to enable PhD students of chemistry to acquire teaching skills?

In order to come closer to answering these questions in initial steps, a comprehensive data analysis was undertaken on the following points (the literature listed is to be seen as examples only):

- A chemist's field of work (GDCH, 2012)
- Professionalisation (of (chemistry) teachers)
  (GROßEBRAHM, 2013; SHULMAN, 1986; URBAN & MEISTER, 2010)
- Subject-related communication
  (DYNKOWSKA, LOBIN & ERMAKOVA, 2012; FIEHLER & SCHMITT, 2004; KULGEMEYER & SCHECKER, 2013)
- Further training in university didactics
  (JOHANNES & SEIDEL, 2012; JUCKS, 2009)
- Design of learning environments
  (COBB & BOWERS, 1999; HÄCKER, HILZENSAUER & REINMANN, 2008)

In order to clarify the framework conditions, an online questionnaire was also carried out with 30 German centres of university didactics which have been set up in recent years to provide qualification for university staff (JUCKS, 2009). The aim of this questionnaire was to find out which subject-related courses are offered for university staff. The questionnaire showed that there are no university didactics courses currently being offered to train teaching skills in the field of chemistry. One of the most frequently cited reasons is the lack of teaching staff for this specific subject. The design experiment is based on this analysis of the current situation.

2.2 Design experiment

2.2.1 First cycle: Study based on interviews and questionnaires with working chemists

Objective: Examination of teaching tasks undertaken by chemists and analysis of the qualification course content they consider necessary.

In order to design a needs-related course, chemists from various professional fields were questioned. Initially, guided interviews were carried out, with open questions being used to gain a more detailed insight into chemists' fields of work.

The interview is structured in four sections.

1. Demographic details
2. Professional activity
   The persons describe their everyday work.
3. Communicating chemical knowledge
   The persons explain what they understand by this and describe their own teaching activities (type, proportion of total working time, preparation and post-teaching work, actual teaching). They also characterise the teaching skills needed for their job.
4. Qualification courses
   The persons name all qualification measures they have already taken in the teaching area (frequency, benefit, content). In addition, they assess how much sense it would make to have qualification courses for PhD students. The persons also state what the contents of such qualification courses could be and assess various contents suggested to them.

In the second step, using qualitative contents analysis (MAYRING, 2002), it was possible both to recognise typical answers in the transcribed interviews and to generate a digital questionnaire with closed questions for chemists working in all professional fields. The structure of the questionnaire was based on the interviews.

The two steps can be seen in Figure 2. A total of 20 chemists (5 women, 15 men) were questioned in the interview study, and 71 (16 women, 54 men) in the questionnaire study.

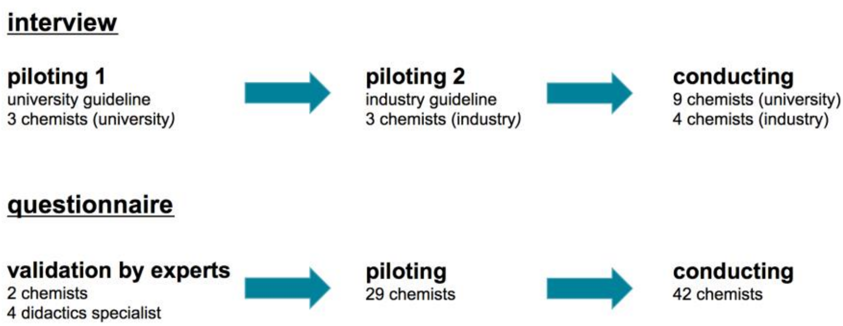


Figure 2: Schematic sequence of the first cycle.

Teaching situations of chemists

The survey shows the variety of teaching situations which the interviewed chemists experience in their everyday working life (cf. Fig. 3). Teaching processes occur, for example, in discussions, lectures and in connection with experts. The greatest challenge in such a process is the wide variety of participants:

> *"I don't have any clear idea about how much I have to tell him, or why and how we do it. So, what I'd like to know is: who are these people, what do they want to hear, what can I tell them at this particular moment, what's the best way to do it, and how much detail should I go into?"*
> (15I, 34:15 min., tfG) (KOLBECK & MAROHN, 2016)

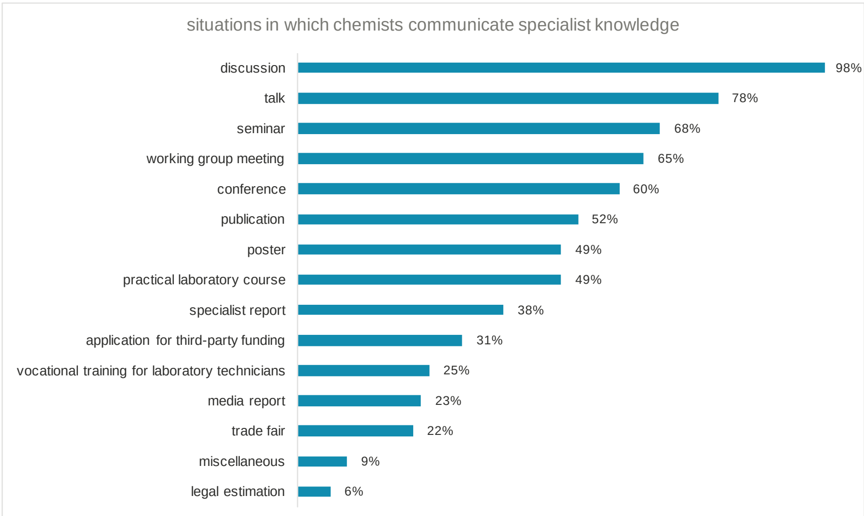


Fig. 3: Depiction of the relative frequencies of the teaching situations of working chemists (n=71; multiple answers).

<u>Qualification contents rated by working chemists</u>

The interviewed chemists said that in their view it would make sense for the contents of the qualification course to include making presentations and posters geared to the audience, as well as sensitisation to difficulties in teaching chemistry. By contrast, almost no importance is attached to PhD students learning how to design typical university teaching situations (e.g. lectures). All the interviewed chemists stated that they would advocate the inclusion of practical exercises (e.g. practice with different types of addressee, video feedback). (cf. KOLBECK & MAROHN, 2016)

2.2.2 Second cycle: Questioning potential participants in the course

<u>Objective:</u> Questioning with PhD students in SFB 858 on contents and general conditions for a qualification course.

In designing the course, it was not only the wishes of working chemists that had to be taken into account, but also those of the people taking part in such a course. The PhD students in SFB 858 were thus questioned using an online questionnaire. The questionnaire contained both open and closed questions on the course content (What issues should be addressed? When would you take part in the course?) as well as questions on general conditions (structure, time required, scope).

What the 20 interviewed PhD students would like to see is a modular, time-variable course which deals with the following questions (cf. KOLBECK & MAROHN, 2016):

- How should I design a good scientific presentation and poster?
- What difficulties can arise when teaching chemistry and how can I deal with them?
- How can I improve my presentation and teaching skills with the help of video feedback?
- How can I communicate chemical knowledge to the respective group of addressees in a suitable way for them?
- How can I look at my abilities with the help of self-reflexion?

2.2.3 Third cycle: Model of necessary teaching skills

<u>Objective:</u> Developing a model which depicts the knowledge and skills needed by chemists to convey chemical knowledge.

In order to be able to design needs-based course, a model was developed in the third cycle which depicts the knowledge and skills needed to communicate specialist knowledge. The model is based on one hand on the insights gained from interviewing the chemists. On the other hand, it is based on a meta-analysis of studies on the following aspects:

- Presentational competence
  (e.g. DYNKOWSKA et al., 2012; HEY, 2011; SCHNETTLER, KNOBLAUCH & PÖTZSCH, 2007)

- Professionalisation of teachers
  (e.g. GROßEBRAHM, 2013; SCHAEPER & BRIEDIS, 2004; WEBLER, 2004)
- Study and vocational requirements
  (e.g. AKESSON et al., n.d.; GDCh, 2012; GDCh, 2003; KLOSTERMANN, HÖFFLER, BERNHOLT, BUSKER & PARCHMANN, 2014)

The key questions in the analysis were:
What must a chemist know and be able to do in order to design a good teaching process? Which skills can be adopted from the field of teacher training? What requirements are there of chemists which characterise teaching skills?

The model developed depicts knowledge and skills in a three-stage matrix (cf. Fig. 4):

A. Fundamentals of cognitive theory (theories and forms of learning)
B. Subject-specific dimension (content knowledge and pedagogical content knowledge)
C. Teaching situation (speaker-addressee relationship and teaching context)
D. Presentation (use of media and design of presentation)
E. Performance (body language and voice)

		I know	II apply	III synthesize	subject-specific concretisation
E	performance	Know the essential apsects of **body language** and **voice.**	Identify and apply the essential aspects of **body language** and **voice** in specific situations.	Assess the application of **body language** and **voice** and draw consequences for teaching processes.	**Body language**: gestures, facial expressions, posture, body movement, handling media, clothes, contact with audience **Voice:** volume, speed, articulation
D	presentation	Know the essential aspects of **using media** and **designing a presentation.**	Identify and apply the essentials aspects of **using media** and **designing a presentatio**n in specific situations.	Assess the application of **using media** and **designing a presentatio**n and draw consequences for teaching processes.	**Use of media**: analogue (board, OHP, flipchart, pinboard, poster, …), digital (beamer, PC, document camera (Prezi, PP), ...), subject-specific (model, experiment, demonstration material), design elements (text, illustration, picture, sketch, drawing, video, audio), laws of perception **Design of presentation:** language (sentence structure, everyday vs. specialist language), argumentation, content, structure
C	teaching situation	Know the essential aspects of **speaker-addressee relationships** and the **teaching context.**	Identify and apply the essential aspects of **speaker-addressee relationships** and the **teaching context** in specific situations.	Assess the inclusion of **speaker-addressee relationships** and the **teaching context** and draw consequences for teaching processes.	**Speaker-addressee relationships:** What is the relationship between speaker and addressee as regards: (previous) knowledge, attitudes, expectations, aims, social roles, interests? **Teaching context:** form (talk, seminar, discussion, specialist report, …), given conditions (rooms, content, external objectives, …)
B	subject-specific dimension	Know the essential aspects of **content knowledge** and **pedagogical content knowledge.**	Identify and apply the essential aspects of **content knowledge** and **pedagogical content knowledge** in specific situations.	Assess the application of **content knowledge** and **pedagogical content knowledge** and draw consequences for teaching processes.	**Content knowledge**: phenomena, terms, laws, models, methods, processes and concepts in chemistry, as well as knowledge gained from current research in chemistry **Pedagogical content knowledge:** ideas about learners, representations, specialist language, didactical reduction, mathematization, …
A	fundamentals of cognitive theory	Know essential **theories** and **forms of learning.**	Identify and apply essential aspects of **theories** and **forms of learnin**g in specific situations.	Assess the application of **theories** and **forms of learning** and draw consequences for teaching processes.	**Learning theories**: constructivism, cognitive theory of multimedia learning, situated learning, … (design of learning environments, visual media) **Form of learning**: methods (e.g. flash feedback), social forms (e.g. working alone, in groups, in pairs)

Fig. 4: Model of knowledge and skills necessary to communicate specialist knowledge, specified for the field of chemical knowledge.

For the operationalisation of the skills, the proposals made by ROLOFF (2012), among others, were used for the classification of learning objectives. We understand the following cognitive processes as related to the operators:

Know: Reproduce and recognise what has been learned.

Apply: Select, identify and apply aspects of what has been learned in line with the particular situation.

Synthesize: Analyse and evaluate a teaching process on the basis of what has been learned, and draw consequences for further teaching processes.

The model can (in principle) be transferred to other subjects. The content specific to the subject of chemistry is in the last column.

The model presented here describes teaching skills which, together with motivational, social and volitional preparedness, show the teaching competence of chemists, in the sense of the term as defined by WEINERT (2001).

The model was validated by nine experts in three sessions (didactics specialists, chemists from industry and university).

The first validations show that this model depicts all the components of a successful teaching process and describes the skills needed.

2.2.4 Fourth cycle: Developing the qualification course

Objective: Developing and piloting the course.

In the fourth cycle, a qualification course was developed on the basis of the model. The design criteria used were the theoretical basics of teaching and learning which have become established in adult education, such as situated, constructivist and reflexive learning (KORTHAGEN & KESSELS, 1999; MANDL, KOPP & DVORAK, 2004; TRIBELHORN, 2007). The course is also characterised by a switch between theoretical and practical phases in order to avoid any acquisition of inert knowledge (HUBER, 2005; WAHL, 2006).

The qualification course

The course consists of four modules, each of which builds on the one before, and which are completed in a given sequence: basics unit, video feedback, poster and application unit. The course comprises 2 ECTS points. PhD students acquire the contents of each unit (in an action-oriented way) while doing practical exercises. The thematic priorities can be seen in Figure 5.

Fig. 5: Visualization of the course and its content (Illustrations based on GrizGraphics) (KOLBECK & MAROHN, 2016).

<u>Basics unit</u>

The basics unit deals with the fundamentals of teaching. PhD students learn in different exercises how to characterise and address different target groups in specific teaching situations. Therefore, different teaching situations are discussed and the constructivist view of learning (DUIT, 1995; RIEMEIER, 2007) as well as subject-specific difficulties (e.g. discrepancy between specialist and everyday language, the advantages and limits of subject-specific models, misconceptions (BARKE, HARSCH, MAROHN & KREES, 2015; PFEIFER, LUTZ & BADER, 2002) are elaborated by the participants in an action-oriented way.

<table>
<tr><th></th><th>Content</th><th colspan="3">Didactic commentary and training of the skills described in the model (cf. Fig. 4)</th></tr>
<tr><td>Duck made from Lego
- Exercise -</td><td>Each participant receives the same six Lego bricks, with which he has to make a duck within one minute.</td><td rowspan="2">Participants experience for themselves the limits of “learning”.</td><td>Make it clear that one term can have associations with different ideas.</td><td>A I</td></tr>
<tr><td>“Then it just has to be explained better ...”
- Exercise -</td><td>Two people, A and B, sit back-to-back. A is given a card with a drawing on it. B is given a blank card of the same size and three different-coloured crayons. A describes his drawing to B in such a way that, at the end, B has replicated the drawing. During the exercise, B is only allowed to say “yes” or “no”. At the end, the drawings are compared.</td><td>Make it clear that ideas cannot be transferred 1:1.</td><td>A I</td></tr>
<tr><td>Learning is ...
- Elaboration -</td><td>... constructive. (Misconceptions (e.g. “Fire destroys”), discrepancy between everyday language and specialist language (e.g. “solve”); working out further examples in pair-work)
... individual. (Presentation of individual ways of learning.)
... situated. (Making it clear that learning is linked to context.)</td><td colspan="2" rowspan="2">Presentation of basic assumptions with a constructivist orientation to explain teaching and learning processes (Riemeier, 2007).</td><td>A I</td></tr>
<tr><td>Communication model
- Elaboration -</td><td>Juxtaposition of the Nuremberg Funnel (Thissen, 1997) and the Constructivist Model of Communication (Kulgemeyer & Schecker, 2013).</td><td>A I</td></tr>
<tr><td>Teaching situations
- Elaboration -</td><td>Presenting possible situations and addressees in potential teaching processes experienced by a chemist.</td><td colspan="2">Making clear to the participants the sense of the qualification course.</td><td>C I</td></tr>
<tr><td>Influencing factors
- Elaboration -</td><td>Listing of different factors that influence teaching processes, such as situation, addressee, speaker, content, visualisation.</td><td colspan="2">Presentation of the aspects, influencing the success of teaching processes.</td><td>A-E I</td></tr>
<tr><td>Previous knowledge in chemistry
- Elaboration -</td><td>Elaboration of subject-specific difficulties in a teaching process such as misconceptions, use of models, specialist language (Barke, Harsch, Marohn, & Krees, 2015).</td><td colspan="2">Elaboration of difficulties, in teaching processes, which are rooted in the subject itself in order to increase participants’ awareness.</td><td>B I</td></tr>
<tr><td>Analysis of addressee
- Elaboration -</td><td>Collection of characteristics of the addressee which influence any teaching, such as motivation, (previous) knowledge, attitude, social role.</td><td colspan="2" rowspan="2">Elaboration of facets and possible ways of interacting to increase participants’ awareness. In addition, concrete tools are provided to ensure addressee-oriented teaching.</td><td>C I</td></tr>
<tr><td>“Storyteller”
- Exercise -
- Elaboration -</td><td>Elaboration of concrete ways of interacting to ensure teaching is addressee-oriented. For this purpose, in this exercise each participant explains to his partner the discovery of the structural formula of the benzene molecule. In doing so, the partner assumes the role of a randomly chosen addressee (e.g. baker, managing director) to whom the teacher must adapt his teaching process. Development of the addressee analysis as an important factor for the teaching to be successful.</td><td>A-C II</td></tr>
<tr><td>Handout</td><td>Addressee-oriented teaching – examples of subject-specific ways of interacting and tips</td><td colspan="2">Participants are given a handout to reinforce what they have learned.</td><td>B,C I</td></tr>
<tr><td>Party
- Exercise -</td><td>Transferring what has been learned to students’ own PhD studies. The participants write a short reply to a question posed by a student of German at a party: “What’s your thesis actually about?”</td><td colspan="2">Participants apply what they have learned to their own situation.</td><td>A-C II, III</td></tr>
</table>

Fig. 6: Structure and elements of the basics unit.

Video feedback unit

The second module takes up the idea of reflexive learning (KORTHAGEN & KESSELS, 1999), which is practised in the form of video feedback. This module is structured in three parts. In the first part PhD students prepare a short talk on their doctoral thesis. This is recorded using a video camera and then reflected by the other PhD students attending to the course upon on the basis of feedback rules already introduced (KOLBECK, 2014) (cf. Fig. 7). In the second part the participants become acquainted with guidelines for designing their PowerPoint presentation (e.g. the laws of perception (HEEGE & SCHMIDKUNZ, 1997) and the cognitive theory of multimedia learning (MAYER, 2005)) (cf. Fig. 8). They elaborate these guidelines for example by preparing a demonstration experiment. On this basis, the participants revise their own PowerPoint slides from the talk they have given. Participants also become acquainted with performance aspects (KNOBLAUCH, 2003). They work on various exercises in the form of a learning buffet to improve their own performance. A few weeks later, in the third part, the same (revised) talk is given in the form of a so-called “stop presentation” (cf. Fig. 7). Here, the presentation is interrupted (“stopped”) as soon as the PhD student reverts to old behavioural patterns which have already previously been critically reflected upon. This means that the PhD student can modify his behaviour directly while giving the talk (WAHL, 2006).

Poster unit

The third module deals with designing scientific posters, in particular the graphic representation of research results and the use of chemical illustrations (cf. Fig. 9). The PhD students reflect on their own posters and revise them on the basis of academic criteria (e.g. HEINRICHS & TROST, 2006; MILLER, 2007; ROWE & ILIC, 2009).

Application unit

In this last unit the PhD students apply their acquired knowledge to authentic situations (TRIBELHORN, 2007). For this purpose, each of them chooses an individual context (e.g. a talk in their working group, a poster presentation at a conference). In doing so, the participants learn how to react appropriately to different teaching contexts and to evaluate the process through self-reflexion.

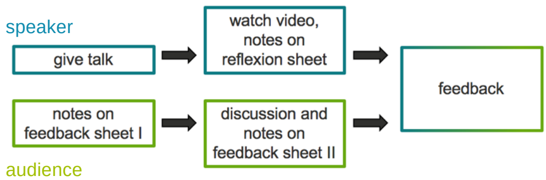
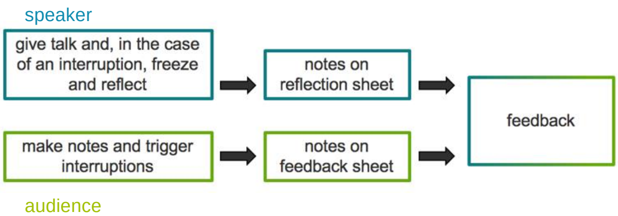
	Content	Didactic commentary and training of the skills described in the model (cf. Fig. 4)	
1st part: video feedback	**Preparation:** Participants prepare a short 10 minute-talk on their own research project for a job interview. **<u>Presentation of video feedback</u>** 	Addressing the idea of reflexive learning (Korthagen & Kessels, 1999). Explanation of the video feedback in the order presented can be read in Kolbeck, E. (2014).	A-C II, III D,E I
2nd part	**2nd part:** Elaboration of design criteria and working on various exercises regarding the individual performance on each participant in the form of a learning buffet. → **Fig. 8**		
3rd part: stop presentation	**Preparation:** Participants make revisions to the short talk mentioned in the 1st part. **<u>Presentation of the stop video feedback</u>** It is made clear beforehand which aspects should trigger an interruption. 	Interruptions to behaviours in the situation itself with the aid of the stop presentation. The aim here is to make unconscious behaviour conscious (Wahl, 2006).	A-C III D,E II, III

Fig. 7: Structure and elements of the entire video feedback unit.

2nd part: Design criteria and performance

	Content	Didactic commentary and training of the skills described in the model (cf. Fig. 4)	
Worst Case - Exercise -	<u>PowerPoint karaoke:</u> Participants must spontaneously give a PowerPoint presentation which they have never seen before.	Creating a stress situation in order to learn how to deal with unknown, stress-inducing situations.	E I
Factors influencing a presentation - Elaboration -	Presenting aspects which influence a presentation and providing a link back to the constructivist communication model in the basics unit.	Showing, and making clear, the complex structure of a presentation.	A-E I
Improving a presentation slide - Exercise -	Elaboration of aspects needing improvement in a given PowerPoint slide on Fischer-Speier esterification.	Elaboration of subjective design criteria for a presentation.	B,C,D II
Design criteria - Elaboration -	Elaboration of the cognitive theory of multimedia learning (Mayer, 2005) and the laws of perception by preparing demonstration experiments (Heege & Schmidkunz, 1997; Schmidkunz & Büttner, 1992). From these, academic design criteria are derived.	Presentation of academic design criteria for a presentation on the basis of cognitive and theories of Gestalt psychology.	A,D I
Transfer to chemistry-specific examples - Elaboration -	Examples of the application of design criteria to formulae (e.g. Schrödinger equation, schemata/mechanisms (e.g. states of matter), presentation of molecules (structural and empirical formula) and diagrams (e.g. NMR/ QCM data)).	Examples of the application of design criteria to subject-specific difficulties. Learning behaviours.	B,D I
Handout part I	Design criteria for a successful presentation	Participants are given a handout to reinforce what they have learned.	D I
Revision of self-produced PowerPoint slides - Exercise -	On the basis of what they have learned, the participants revise their own PowerPoint slides from the talk they gave.	Applying what has been learned to reinforce this knowledge.	D II, III
Performance - Elaboration -	Presentation of factors influencing the performance (e.g. body language, gestures, facial expressions, contact with audience, voice and language).	Presentation of aspects of a performance to make clear the effect of body language and voice.	E I
Training performance - Exercise -	Work on various exercises in the form of a learning buffet to improve students' own performance (e.g. on posture and the use of filler words).	Each participant has the opportunity to work on his behaviours. Autonomous learning is called for here.	E II
Handout part II	Performance aspects	Participants are given a handout to reinforce what they have learned.	E I
Authenticity - Elaboration -	Explanation of the fundamental role played by authenticity for a successful presentation.	Participants should be relieved of any pressure or fear of not being perfect.	E I
Dealing with stage fright - Elaboration -	Showing the positive aspects of stage fright; collecting ways of dealing with stage fright.	Reference back to the beginning of the unit so that stress situations can be successfully dealt with.	E I

Fig. 8: Structure and elements of the video feedback unit, part 2.

	Content	Didactic commentary and training of the skills described in the model (cf. Fig. 4)	
Preparation	Participants' current posters are displayed in the form of a walk around a museum.	Participants' own posters as the starting point.	
Assessment of posters - Exercise -	Posters of which participants have a positive impression are marked using two adhesive dots of the same colour.	Intuitive assessment of posters. It is made clear that the first impression is often decisive when looking at a poster again.	D III
Criteria for a good poster - Elaboration -	Presentation of the aspects making up a good poster such as text quantity, choice of colours, reader orientation, structure, laws of perception (Heege & Schmidkunz, 1997), illustrations.	Presentation of the academic basis for the design and assessment of posters.	D I
Handout	Designing a poster	Participants are given a handout to reinforce what they have learned.	D I
Designing a poster - Exercise -	At the computer the participants design posters showing the Wittig reaction. For this, various elements are available to them.	Application of what has been learned to an unprepared chemical topic. Participants must select aspects they have learned and apply them to specific situations.	D II
Improving one's own poster - Exercise -	Participants give each other feedback on their posters, using coloured post-its. *Red*: You can improve this. How? *Green*: I like this a lot. Why? For every red post-it, a green one must be used too.	Participants receive individual, concrete feedback on their own posters.	D II, III

Fig. 9: Structure and elements of the poster unit.

In order to further develop the course step by step, it was pre-tested three times with three or five PhD students in each case.

The test-runs of the individual modules were recorded on video in order to identify any possible potential for improvement. The increase in knowledge displayed by the PhD students was checked using a pre-post design. In addition, the students' learning process was analysed with the aid of portfolios (BRUNNER, KRIMPLSTÄTTER & KUMMER, 2011). The key questions for improving the course were:

- How do the participants assess the course? What changes would they suggest?
- In practice, which aspects of the course are different from what they expected?
- Are there any initial indications of learning progress made by the PhD students?
- Does the course help the participants to acquire the skills shown in the model?

2.2.5 Fifth cycle: Main test-run and analysis

Objective: Conducting and evaluating the qualification course.

This cycle is designed to provide an answer to the question of whether the course developed is suitable for training teaching skills in PhD students of chemistry. The course is conducted in three run-throughs, each with five or six participants. Afterwards the students' learning progress is analysed using mixed methods (JOHNSON & ONWUEGBUZIE, 2004). For data-gathering purposes the following are used:

- **Pre-post questionnaire**
  (recording increase in students' knowledge → see columns I, II of the model, Fig. 4)
- **Portfolio** with questions prompting self-reflexion
  (observing the students' learning processes → columns II, III)
- **Criteria-guided assessment** by experts of participants' presentations and posters before and after taking part in the course
  (review of the application of what has been learned → column III)
- **Guided interviews**
  (recording students' knowledge and attitudes and their application of what they have learned → columns I, III)

This cycle is currently at the state of data preparation and analysis, which means that only temporary results can be shown. Then data was analysed using qualitative content analysis.

Reaction of the participants

12 of 17 participants rate the course with school grade “very good” and 5 with “good”. The participants justify their ratings especially with relevance for the individual person (e.g. knowing their own fields of development) or with the structure of the course (e.g. mixture between theory and practice):

> *“I like the course, because there were alternating theoretical und practical phases – theoretical contents could be applied to one’s own presentation.”* (test person (tp) 16; tfG)

Participants liked the following aspects of the course especially:

- content conception of the course (e. g. video feedback, analysis of addressees)
  “I like the video feedback very much. I like the evaluation of personal achievements (poster or talk) to improve myself by using concrete examples, too.” (tp 17; tfG)
- methodological diversity
  “The changing methods; that way, I was concentrated although it was Monday morning.” (tp 8; tfG)
- focus on the individual person
  “Not only general and frontal instructions were given, so that one could deal with one’s own strengths and weaknesses.” (tp 12; tfG)
- materials (e. g. performance exercises, handouts)
  “Exercises to improve one’s teaching skills (e.g. you get a straight stand when you put a small bag on your head).” (tp 9; tfG)

Overall, participants responded positively to the course’s framework. They enjoyed pleasant learning atmosphere, they considered the quality of the materials as good, and they found the course useful. Furthermore, 70% of the participants were satisfied with the duration of the course.

In addition to that, 71% of the participants found the contents of the course very relevant. They reason for the relevance were especially job requirements or improving oneself:

> *"Now I've got a better understanding of my own teaching skills and know what I have to improve."* (tp 10; tfG)
>
> *"In my future working live, I'll often get into situations where I will have to communicate chemistry or present myself or a company. I've learned a lot to improve myself regarding these things."* (tp 15; tfG)

From the participants' perspective, the developed course differs from other university courses in the following aspects:

- participant's high activity
  "Many practical phases, not only frontal instruction." (tp 7; tfG)
- regarding individual needs
  "Every individual person was focused. Usually, there are more than 20 people in university courses and then they only talk about general information." (tp 8; tfG)
- conception takes the addressees into account
  "This course is really designed for chemists." (tp 15; tfG)

Course's effects

All participants believe that they've improved their knowledge and skills regarding the communication of chemistry. Knowledge, exercises, feedback and discussion are the four aspects PhD students think have helped to improve their knowledge and skills. Each student rate the four aspects differently. It will be interesting to find out in further analysis if design criteria can be developed for courses that regard different types.

It is noteworthy that some participants developed their own ways to handle difficulties in their performance. For example, after a video feedback, one participant sets an alarm in his mobile phone to be reminded daily to speak slowly. Another participant explained that he watches out for fillers in his everyday life:

> *"It's awful participating in this course. Whenever I talk to someone and I use fillers, I say "stop" or "car" or something else in my head [like I have to do in an exercise]. […] But that really works to use less fillers."* (tp 13; tfG)

2.3 Re-Framing

An analysis of the final answer to the question of how PhD students improve their presentation skills by means of this course is not yet possible to present. However, first results indicate that the designed course contributes to the development of teaching skills among PhD students. Furthermore, results also show the good reaction of the participants to the course according to KIRKPATRICK (KIRKPATRICK & KIRKPATRICK, 2013).

The model, validated by experts (Fig. 4), has proven itself to be a suitable basis for developing a didactic subject course. To what extent the model can be transferred to other disciplines is something that remains to be clarified and tested in further studies. What is also needed is further studies to ascertain which section of a chemist's professional competence the teaching competence can be allocated to.

The project presented here describes the first steps in training professional chemists in the field of communicating chemical knowledge as part of their doctoral education.

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