The project CHEMOL: Science education for children - Teacher education for students!

Mirjam Steffensky[a]* and Ilka Parchmann[b]

[a]*University of Lüneburg, Chemistry Education, Lüneburg, Germany*
[b]*University of Oldenburg, Education in Chemistry, Oldenburg, Germany*
e-mail: steffensky@uni-lueneburg.de

Received 13 August 2006, accepted 10 February 2007

Abstract: The project CHEMOL (CHEMistry in Oldenburg) has developed a structure that integrates laboratories for primary-school children into the university education of teachers, both as in-service and teacher training programmes. The CHEMOL lab is visited once or twice a week by different classes. Supported by members of the team and teacher-training students, the children investigate phenomena about fire, water, air, and solids in small groups and they develop and carry out simple experiments themselves. For the visiting children, CHEMOL aims to develop a general understanding of basic concepts of science (with a special focus on chemistry) and basic experimental skills. For student teachers, the project offers the possibility to plan and carry out experimental work with young children and to observe and discuss the children's ideas. Thus, the CHEMOL project gives the students a chance to transfer their theoretical knowledge about teaching and learning science into practice already during their study time at university. The conceptual approach and results of a small accompanying interview study is discussed in this paper. **[***Chem. Educ. Res. Pract.***,** 2007**, 8** (2), 120-129]
Keywords: teacher education, university science labs, primary school

Introduction and background of the teacher education project

In most countries, the balance between practice and theory is a perennial issue in teacher education. Although teacher education programmes may vary in different countries, there is a tendency that university education is mainly responsible for theoretical education, while pre-service teacher training in schools offers the practical experience (e.g. Ball, 2000). The situation in Germany exemplifies this statement: teacher education comprises a first component at university followed by a training-on-the-job for one and a half or even two years at school. Many student teachers and practising teachers complain that they are not able to see the relevance of the pedagogical theories they learn at university; instead, they rather assume teaching as being mostly common sense and learned through experience. This may be a consequence of the way teacher education is organised.

The development of pedagogical content knowledge (pck, as described by Shulman, 1986) is promoted by the use of content knowledge and (just beginning) pck in pedagogical contexts (Van Driel et al., 2002). Possible pedagogical contexts are classroom experiences or, for example, microteaching approaches. Some findings indicate that school placement is not always as successful as assumed. For example, sometimes there is a great pressure to cover a given curriculum and no time for reflection on the experience gained. Furthermore, cooperating teachers are strong role models, and in some replies there is a mismatch between their teaching practice and the goals of teacher education programmes (Hewson et al., 1999). Studies on the effectiveness of microteaching show varied results. The investigated approaches include different strategies, which makes it difficult to compare the results. In all, microteaching seems to facilitate the acquisition of teachings skills, but it is not clear if there are transfer- and long-term effects, nor which features of the approaches are crucial for effectiveness (Klinzing, 2002).

The impact of teacher training programmes on the quality of classroom activities is not easy to study. However, several studies indicate that the initial knowledge of young teachers based on their own positive and negative school experiences is very stable, and represents an important base for classroom practice, especially in situations where fast decisions are necessary (e.g. Ball et al., 1999, Van Zee et al., 2001). If teachers change their initial teaching and their attitudes during their first years, they often do not shift towards a more sophisticated insight into learning and teaching, but rather towards the well-established practices of the school where they now teach (Müller-Fohrbrodt et al., 1978). Theories students have once learned at university courses are kept merely for examination purposes, but not actually to guide their teaching. Hence, there is no apparent need for further theories and professional learning.

In recent years reflection became a key concept in teacher education for making changes in teaching (Yerrick et al., 2005). Reflective practice is an integral part of professional practice and fundamental for life-long professional development (Hewson et al., 1999). Some teacher education programmes integrated action research projects (Tabachnik et al., 1999) or comparable projects (Kleickmann et al., 2005), where prospective teachers engage particularly in reflective practice. For example, these approaches helped student teachers to understand and elicit students' thinking and their prior knowledge, but do not guarantee that they employ their knowledge in the classroom (Hewson et al., 1999). Factors that hindered the teaching to effect conceptual change in this example included their own beliefs, the scarcity of school placements and their fragmented content knowledge (Tabachnick et al., 1999).

Currently in Germany and in the Netherlands, as in some other countries, teacher education is changing towards a Bachelor- and Master-system. In this process of developing new curricula, the goal of a better integration as described above has moved centre stage again; the enhancement of the integration of (university) theory and (classroom) practice seems to be a common trend in the recent development of teacher education programmes (De Jong et al., 1998). In Germany, for example, several new approaches integrate a half-year field training in school at the beginning of the training course, although the results of the effect of those approaches are not yet clear. A simple transfer from theoretical knowledge into classroom activities is surely not possible (Kolbe, 2004), even though some students have this expectation.

In this paper, we discuss an approach for prospective primary and secondary teachers that provides small group and short duration teaching and learning activities. Here student teachers can use their beginning pck in a pedagogical context and reflect on their experience together in groups of different backgrounds. The project called CHEMOL (CHEMOL an acronym from CHEMistry in OLdenburg) is part of the teacher education in Oldenburg and Lüneburg. To get an insight into the effects of this integrated module, we are carrying out several research studies; here we discuss the results of the first explorative and qualitative interview-study.

Context of the study

The project CHEMOL for children and teachers

Primary school classes visit the CHEMOL labs in Oldenburg and Lüneburg for half a day. The project began in 2002 and more than 9000 children have visited the CHEMOL lab since then. In the lab, classes are divided in groups of three or four children, which investigate chemical and physical problems, supported by staff members and student teachers. The lab visit is organised as learning cycles: phenomena about water, air, fire and solids are presented to the groups of children and are meant to raise questions. These questions are investigated by the children following their suggestions, or other ideas from the programme and from our former experiences. Normally, each group will have investigated two or three areas during the half-day visit. The schoolteachers, who organise the visit, receive the material in advance and are asked to prepare the children, for example about safe behaviour in lab.

The idea to offer science labs to schoolchildren and to invite them to visit a university has become popular in Germany during the last few years. Many universities give lectures for children, so called ‘Kinderuniversität’ (kids’ universities). Some have designed special lab-work activities for children. One reason for this development was the decreasing numbers of students in sciences, especially in the ‘hard sciences’, such as physics, chemistry, or engineering (Gago et al., 2004). Accordingly, most projects are aimed at students who will decide their career pathways in the near future, students of A level-type courses, for example. The CHEMOL project starts at the other end; we try to foster the interest and motivation of young children and to enhance their background knowledge about the sciences very early on.

There are many reasons to start such activities with young children. Firstly, empirical studies show that primary school children are highly motivated for (simple) scientific investigations and questions (Martin et al., 1997). We can also observe this motivation in the CHEMOL lab as reported by the children and their teachers in questionnaires and by the letters we receive from the children. Secondly, research studies show that young students are well able to develop basic ideas and explanations about scientific phenomena and inquiry (e.g. Metz 1998, Bullock et al., 1999).

Nevertheless, chemistry, physics, or technology topics often get little attention in primary schools in Germany, as in other countries, as shown in several analyses of syllabuses and teaching protocols (e.g. Einsiedler, 2002; Appletown, 2003). This situation cannot be ascribed to the students but rather to the teachers. Primary-school teachers usually have no science background. Even though many of them are interested in science, they admit that they do not feel able to teach sciences (with the exception of biology) (e.g. Harlen, 1997; De Jong et al., 2002).

The aim of the project to foster the interest of young children can only be achieved if teachers take up the new ideas from the CHEMOL visit and continue the work in school. Otherwise, the visit is a single event, and its effects are not very lasting. Therefore, CHEMOL also offers special in-service training workshops, where primary teachers can acquire the necessary knowledge and skills by carrying out the experiments themselves, supported by university staff members. The CHEMOL laboratory shows teachers experiments (Jansen, 2005) they can integrate into their normal lessons at school. For the experiments, only simple, everyday materials such as soda and vinegar are needed, special laboratory equipment is not required and, of course, none of the materials is harmful. The additional (supplied) teaching material includes possible connections to the syllabuses or to optional subjects, and more information about the experiments. Hence, the CHEMOL project is not only for children; it is also designed to improve teacher education.

Nevertheless, a questionnaire study shows the difficulties of incorporating science teaching into the teachers’ own routines at school, although primary teachers evaluated the project positively and consider the motivation and the learning achievement of their pupils as high (for more details see Steffensky and Wilms, 2006). Missing knowledge was most often named as a reason for not carrying out such activities in school. This indicates that the integration of scientific work with children into teacher training for primary schools is important both at the university level and in professional development courses for in-service teachers.

Integration of the CHEMOL project into teacher training

Those students in this project, who aim to teach in secondary schools, study chemistry, biology or physics, while those heading for primary schools usually study biology if they study sciences at all. The concept of 'learning communities' (Eilks et al., 2004) suggests an opportunity for the students to exchange their specific expertise and learn from those of the other groups, since primary-school student teachers often have a better pedagogical background, while the secondary school student teachers have a better command of concepts and skills in sciences. This can also help to establish future patterns of cooperation with colleagues in school.

Student teachers carry out the CHEMOL project normally for four months; at first, participants get an introduction into the theories of children's learning (science) and to the experiments and corresponding basic concepts, the latter is especially important for non-chemistry students. The next step is to observe school classes during their visit at the CHEMOL lab. Thirdly, the student teachers work with groups of children themselves. During these weeks of practical work with the children, there are regular meetings of the students, where they analyse and discuss their experiences and observations. Within the whole learning community, the students form pairs so they can observe each other and consider the learning and teaching situation from two perspectives. Supervising science lecturers also provide feedback. Additionally, some groups are videotaped; these tapes are also used for individual feedback and group discussions. Finally, for their term paper students are asked either to develop an experiment or series of experiments that can be integrated in the course in the future, or to investigate a small research topic. The research questions can be specific ideas or learning difficulties children have, for example. During the phases of reflection, and for their term paper, students have to connect their own experiences and observations to their pedagogic content knowledge. The results are used to optimise the CHEMOL project, which can therefore be regarded as a research based developmental project (Eilks et al., 2004), integrated into the teacher training at university level.

Compared to their future school experience or internships in school, the student teachers have the opportunity during the CHEMOL project to concentrate on teaching and learning sequences, as they do not have to worry about classroom management or preparation of lessons and courses. This reduction of complexity in a teaching situation seems advantageous for the learning of the prospective teachers, especially at the early stages.

Data collection and analysis

Participants of the study (N = 15) were interviewed individually six months after they had participated in the project about their experiences during the course. All the students were in the last third of their university studies. They joined either a chemistry-teaching or physics-teaching programme (3 male, 7 female) or a primary teaching programme (5 female). The interviews lasted on average 40 minutes; they were conducted at the university and were audio taped. The interviews were semi-structured, and allowed the respondents to introduce new issues and tell 'their own stories'. They were based on five open-ended questions:

1. What motivated you to participate in the course?
2. What difference do you see between this course and other practical training courses in school?
3. On which specific aspects of the teaching and learning process did you focus during the course?
4. Did your chemistry content knowledge increase during the course? If so, to what extent?

5. Could you use the acquired knowledge (content and pedagogical content knowledge) and experiences in other courses at university?

The interviews were transcribed for analysis, which involved a process forming categories emerging from the data, categorization of the data, and paraphrasing and summarizing of the coded parts of the transcript. The main aspects (qualitative and quantitative) of the categories are described in the following part. For illustration, some quotations are used, which we translated from German into English, here we tried to strike the right note. This is an additional problem of interpretation; therefore, we made less use of quotations than in some other research reports. The following results refer to the interviews. The videotapes and other observations were not used for deeper analysis, because not all of the interviewed participants were recorded and even when they were, it was not necessarily at the same phase of the project, which makes comparison difficult.

Results

As is known from many research studies, student teachers and in-service teachers criticise the lack of practice orientation in most teacher programmes (e.g. Bohnsack, 2000). Consequently, courses in which teaching practice plays a central role should be popular among teacher students. Indeed, all fifteen student teachers interviewed named this as their main motivation to participate in the course. Working with 'real' children is such an attraction that even chemistry is accepted ("*I can't stand chemistry, but I liked the idea of working with kids, so I decided to put up with it.*"). Besides, student teachers were interested to find out about new experiments for children and to be better trained in handling experiments.

As expected, all teacher students named several organizational aspects, which differ between an internship in school and the CHEMOL project. The main difference participating student teachers mentioned was the focus of interest. In the CHEMOL course, the children and their learning are the focus of interest (11 replies), whereas the preparation of lessons and learning arrangements (7 replies) as well as classroom management (14 replies) were indicated to be the major foci of school practice. Differences between the types and process of reflection are described, too (9 replies). The responses from the in-service teachers centred more on the content, for example on the chosen materials or experiments, or on class management. Particularly in the latter areas, much practical advice can come from the experienced in-service teacher. Reflection on the CHEMOL project refers more to subject-oriented theoretical and empirical findings and teaching behaviour/behaviour patterns and is seen as being more general and abstract. In contrast, reflection and feedback in a training course in school concentrates on the concrete situation, where it is usually the planning and the execution of teaching programmes that are discussed and not teaching behaviour. At least this is what student teachers feel. ("*In school we hear about many tricks, for example how to get a class to be quiet; in the CHEMOL project attention is much more on the principles. In CHEMOL I started to think about teaching, learning, and myself in the teacher role; I know that is important, even if it does not lead to clear advice how to do things*"). Only one student saw no difference at all.

A very important difference in the two settings, as thirteen of the interviewed participants pointed out, is a higher sense of security the CHEMOL project provides. Therefore, these factors are important

- a small group of children is involved instead of a whole class (13 replies)
- the teaching and learning sequence is repeated several times (13 replies)
- there is not somebody (with years of teaching experience) watching the whole time (8 replies)
- the children in the CHEMOL are mostly highly motivated (5 replies)

- there is greater confidence in being able to handle the situation (4 replies).

Correspondingly, the respondents explained that the aspects they focused and reflected on changed over the time of participating in the project (12 replies). At first, the handling of the experiments, the theories behind the experiments, the concern about using the correct terms (both mentioned only by the students of the primary-school programme), and the organisation of the programme itself captured much attention. After repeating the learning sequence four to six times with different groups and gaining confidence, the students became more aware of pedagogical or pck aspects. Some aspects mentioned were

- letting the children plan and do the experiments more on their own (11 replies)
- reducing the need for explanations by the teacher (11 replies),
- changing the sequence of experiments, for example, because the children have less or more experience and/or knowledge than expected (6 replies),
- taking up new ideas from the children to lead the investigation (5 replies),
- asking the children more precisely about their ideas and mental models (4 replies),
- using appropriate language consistently (4 replies).
- comparing different approaches (2 replies)
- anticipating mistakes and trying out different patterns of response to those mistakes (2 replies),
- differentiated and adapted behaviour towards less gifted and more gifted students (1 case).

All five students at the primary-school teacher programme reported a great increase of subject matter knowledge, which is expected, considering the poor knowledge in the 'hard' sciences primary teachers often have or are assumed to have (e.g. Asunta, 1997). Although they still assessed their general content knowledge as poor, they were persuaded to introduce the experiments into their own school practice later on. Two of them have meanwhile written their master's thesis on chemistry topics in primary schools. Additionally, eight of the secondary trainee teachers reported a moderate increase of their subject-matter knowledge, whereas two other students reported only a small increase, if any at all.

The student teachers used their experiences from the CHEMOL project to a great extent in other (school) experimental courses, as well as in their teaching practice (9 replies). Not only was the additional experience in experimentation felt to be helpful, but also the experience in arranging a teaching and learning situation that incorporates an experimental approach.

Besides, in so-called theoretical courses on general or science education the knowledge developed in the CHEMOL project was considered to be helpful. It seems as if the episodic knowledge developed in the CHEMOL project can lead to theoretical knowledge. Student teachers get to know a variety of examples, particularly of children's ideas and informal concepts and strategies in (experimental) learning situations (5 replies) as well as typical patterns of teacher behaviour (7 replies), they had recognized in their own behaviour. These examples and their reflection illustrate theoretical knowledge. One student explained: "*I can picture a bit better what theories can mean for practical classroom work, because I have more examples in mind*".

Discussion

The numbers of student teachers participating in the project, as well as their responses to the project, indicate the interest for such activities. Within teacher training, CHEMOL offers student teachers the possibility to acquire practice or experience in theory-based analysis of and reflection on teaching and learning processes and on lab work. An important feature of this project is the possibility of repeating learning sequences with different groups. On average, student teachers repeat a learning sequence with twelve different groups during a term. The more students feel comfortable with the experiments and the new teaching situation, the more they start to try out different things, for example to change the order of experiments or to let the children do more work on their own, so the learning processes of the primary school pupils become more important. The experiments are not very complicated, either in the required experimental skills or in the scientific content, and the participating student teachers practice them several times before they start work with the children. Nevertheless, it takes several repetitions until the learning of the children, their difficulties, and concepts can become the centre of attention.

Our observations of the student teachers match their own estimation about the need for up to seven repetitions until they can confidently focus on the children's learning processes. Independently of the interviews, we noticed that the student teachers need more time (from about 50 to 60 minutes) for one learning sequence with a single student group after the first six or seven repetitions. This is understandable, if we consider that as student teachers gain confidence they keep more in the background, and give the primary students more space and time to work on their own problem solving, so they need more time for the learning cycle overall.

This focus is important because learning, and knowing and understanding of specific learning difficulties and students' conceptions are a key element of pedagogical content knowledge (Van Driel et al., 1998). The use of theoretical knowledge in various contexts supports the development of pck (Ball, 2000**)**. At the same time (reflected) experiences seems to support an access to theoretical knowledge (Nölle, 2002), as the students stated in the interviews.

Some studies indicate that student teachers tend to change their behaviour during their teaching practice aiming for a stronger control over the class; at the same time they become less inclined to try things out (Hascher 2006; p. 132). This desire to control, Jones and Vesilind (1995) argue, emerges from the need for student teachers to reduce the complexity of classroom environments. School training is obviously necessary, but in addition, projects such as the one described here offers a setting of reduced complexity, which can be an opportunity for learning about (individual) teaching and learning processes.

One can also use the CHEMOL project for the training and development of innovative teaching ideas. In a usual internship situation, this is sometimes difficult, because there are so many factors to consider, so that the introduction of a new idea, possibly without the support of supervising in-service teachers, is difficult. Especially for primary trainee teachers, mostly without a science background, the project offers a rare opportunity: Here students have the chance to deal with science topics for a longer period and to put this into practice teaching and learning with children straight away. This could be a chance for primary teachers to develop greater confidence in their own scientific knowledge and ability to teach science, which then promotes the implementation of chemistry and physics in primary school classes. At the same time, beginning teachers could disseminate new ideas in their future schools. The analysis of these possible effects must involve long-term studies.

However, especially for beginning teachers, the setting up of more extensive experimental courses seems to be difficult, because in this period time pressure is extremely high or is assumed to be so. Beginning physics teachers, who definitely have more experimental experiences than primary-school teachers for example, name experimental courses as a special burden during the first years at school (Merzyn, 2004). For this reason, it seems that projects like CHEMOL are not only a chance for primary school teachers but also for secondary science teachers to achieve more practice in experimental work with children. Furthermore, working on basic science concepts or phenomena can be helpful for schoolwork alongside the often rather specialised courses or topics in university education. Some studies revealed that both trainee and experienced teachers criticise the emphasis on the teaching of specialised knowledge instead of a broader, more school-related knowledge in universities (Merzyn, 2004). Our finding, that not only the prospective primary teachers, but also some of the chemistry student teachers described an increase of their content knowledge might be due to fact that the topics they study during the CHEMOL course are very different from those of the usually (more specialised) chemistry courses.

Although not part of our research study, we noticed that the observation of selected video sequences during the coursework often initiates discussions on general educational issues, such as explaining, dealing with mistakes, types of questions, or common misconceptions. We also observed that sometimes student teachers raised questions that arose from pedagogic theories in a practical context.

Similar experiences are also described for multimedia learning environments in teacher education, for example the MILE project (Oonk et al., 2003). In MILE, records of teaching practice in an actual classroom setting are used for math teacher education. Despite these positive effects, it is crucial to define theory-grounded criteria for analysing and discussing the videos or the observations student teachers made in the CHEMOL lab. Otherwise, there is a risk of remaining on a superficial level or not moving beyond basic common sense. The small research questions students work on for their term papers proved to be helpful. Working on those during the course often gave a positive impetus to the discussions. With the formed (feed-back) pairs and/or the video feedback student teachers can practice observing, analysing and reflecting individually and in a team. All this is the basis for peer coaching and team coaching or social support in general, which is a key factor for life-long professional development.

The results from the first interview study are based on self-assessments of the prospective teachers. This approach requires that participants can see themselves retrospectively in a realistic manner and that they do not just provide socially desirable answers. In the future, we plan to assess formally the development of pck and content knowledge during the course. Besides that, another important research question is whether the knowledge and experience developed in the CHEMOL project have an impact on classroom activities in training courses or in the long term on teaching activities in schools. Knowing the barriers to the implementation of new teaching methods, topics, approaches and contexts into school practice, this will be the actual test of the effectiveness of the project. Time will tell.

Acknowledgements

The authors thank the CHEMOL project group in Oldenburg and Lüneburg for their continuous assistance and support of the project. Furthermore, the authors thank the ‘Fonds der Chemischen Industrie’ in Germany, for the financial support of the project.

References

Appleton K., (2003), How do beginning primary school teachers cope with science? Toward an understanding of science teaching practice, *Research in Science Education,* **33**, 1–25.

Asunta T., (1997), In service science courses for primary teachers: implementation of different types of in service training courses in Finland, *Science Education International,* **8**, 18-23.

Ball D.L., (2000), Bridging practices. Intertwining content and pedagogy in teaching and learning to teach, *Journal of Teacher Education,* **51**, 241-247.

Ball D.L. and Cohen D.K., (1999), Developing practice, developing practitioners: toward a practice-based theory of professional education. In G. Sykes and L. Darling-Hammond (Eds.), *Teaching as the learning profession: Handbook of policy and practice*, San Francisco: Jossey Bass, pp. 3-32.

Bohnsack F., (2000), Probleme und Kritik der universitären Lehrerbildung. In M. Bayer, F. Bohnsack,, B. Koch-Priewe, J. Wildt, (Eds.), *Lehrerin und Lehrer werden ohne Kompetenz? - Professionalisierung der Lehrerbildung*, Klinkhardt, Bad Heilbrunn, 56 pp.

Bullock M. and Ziegler A., (1999), Scientific reasoning: developmental and individual differences. In F.E. Weinert, W. Schneider (Eds.), *Individual development from 3 to 12. Findings from the Munich Longitudinal Study*, Cambridge University Press, pp. 38-44.

De Jong O., Korthagen F. and Wubbels T., (1998), Research on science teacher education in Europe: teacher thinking and conceptual change, In B. Fraser and K.G. Tobin (Eds.) *International Handbook of Science education*, Kluwer Academic Publishers, Dordrecht, pp. 745-758.

De Jong O, Veal W.R. and Van Driel J.H., (2002), Exploring chemistry teachers knowledge base. In J.K. Gilbert, O. De Jong, R. Justi, D. F. Treagust, J. H. Van Driel (Eds.) *Chemistry education: towards research-based practice*, Kluwer Academic Publishers, Dordrecht, pp. 369-390.

Eilks I., Parchmann I., Ralle B. and Gräsel C., (2004), Changing teachers' attitudes and professional skills by involving them into projects of curriculum innovation in Germany. In: B. Ralle, I. Eilks (Eds.), *Quality in practice-oriented research in science education, Tagungsband zum internationalen Sommersymposium in Dortmund*, Shaker-Verlag, Aachen, pp. 29-40.

Einsiedler W., (2002), Empirische Forschung zum Sachunterricht. Ein Überblick. In K. Spreckelsen, K. Möller, A. Hartinger (Eds.), *Ansätze und Methoden empirischer Forschung zum Sachunterricht, Forschungen zur Didaktik des Sachunterrichts, Bd. 5*., Klinkhardt-Verlag, Bad Heilbrunn, pp. 17-38.

Gago J.M., Ziman J., Caro P., Constantinou C., Davies G., Parchmann I., Rannikmäe M., and Sjoberg S., (2004), *Europe needs more scientists, Report by the High Level Group on Increasing Human Resources for Science and Technology in Europe 2004*, European Commission.

Hascher T. (2006), Veränderungen im Praktikum – Veränderungen durch das Praktikum, *Zeitschrift für Pädagogik*, **52**, 130-148.

Harlen W., (1997), Primary teachers' understanding in science and its impact in the classroom, *Research in Science Education*, **27**, 323–337.

Hewson P.W., Tabachnik R., Zeichner K.M. and Lemberger J., (1999), Educating prospective teachers of biology: findings, limitations, and recommendations, *Science Education*, **83**, 373-384.

Jansen W.. (Ed.) (2005), *CHEMOL – Heranführen von Grundschulkindern an Chemie und Naturwissenschaften*., Aulis Verlag, Köln.

Jones M.G. and Vesilind E., (1995), Preservice teachers' cognitive frameworks for classroom management, *Teaching and Teacher Education*, **11**, 313-330.

Klinzing H.G., (2002), Wie effektiv ist Microteaching? *Zeitschrift für Pädagogik*, **2**, 194-214

Kleickmann T., Gais B. and Möller, K., (2005), Lehrervorstellungen zum Lehren und Lernen im naturwissenschaftsbezogenen Sachunterricht – Gibt es einen Zusammenhang zwischen Vorstellungen und Lehrerausbildung? In: Cech, D., Giest, H. (Eds.): *Sachunterricht in Praxis und Forschung*, Bad Heilbrunn: Klinkhardt, pp. 167-176.

Kolbe F.-U., (2004), Verhältnis von Wissen und Handeln, In S. Blömeke, P. Reinhold, G. Tulodziecki, J. Wildt (Eds.), *Handbuch Lehrerbildung*, Klinkhardt-Verlag, Bad Heilbrunn, pp. 206-231.

Martin M.O., Mullis I.V.S., Beaton, A.E., Gonzales E.J., Smith T.A. and Kelly D.L., (1997), *Science achievement in the primary school years: IEA's third international mathematics and science study (TIMSS)*, Chestnut Hill, MA: Boston College.

Metz K.E., (1998), Scientific inquiry within reach of young children, In B.J. Fraser and K.G. Tobin (Eds.), *International Handbook of Science Education*, Kluwer Academic Publishers, Dordrecht, 81-96.

Merzyn G., (2004), *Lehrerausbildung- Bilanz und Reformbedarf. Überblick über die Diskussion zur Gymnasiallehrerausbildung, basierend vor allem auf Stellungnahmen von Wissenschafts- und Bildungsgremien sowie Erfahrungen von Referendaren und Lehrern*, Schneider Verlag Hohengehren/ Baltmannsweiler, 56pp.

Müller-Fohrbrodt G., Cloetta B. and Dann H.-D., (1978), *Der Praxisschock bei jungen Lehrern. Formen - Ursachen - Folgerungen*. Klett-Verlag, Stuttgart.

Nölle K., (2002), Probleme der Form und des Erwerbs unterrichtrelevanten pädagogischen Wissens, *Zeitschrift für Pädagogik*, **48**, 48-67.

Oonk W., Goffree F. and Verloop N., (2003), For the enrichment of practical knowledge: good practice and useful theory for future primary teachers, In: J. Brophy (Ed), *Using Video in Teacher Education*, (Vol. 10, Advances in Research on Teaching), pp. 131–167.

Shulman L.S., (1986), Those who understand: knowledge growth in teaching, *Educational Researcher*, **15**, 4-14.

Steffensky M. and Wilms M., (2006), Chemisches Experimentieren im Sachunterricht – welche Impulse geben Schülerlabore und Lehrerfortbildungen? *Chemie konkret*, **13**, 14-20.

Tabachnik B.R. and Zeichner K., (1999), Idea and action: action research and the development of conceptual change teaching of science, *Science Education*, **83**, 310-322.

Van Driel J.H., De Jong O. and Verloop N., (2002), The development of pre-service chemistry teachers' pedagogical content knowledge, *Science Education*, **86**, 572-590.

Van Driel J.H., Verloop N. and De Vos W., (1998), Developing science teachers' pedagogical content knowledge, *Journal of Research in Science Teaching*, **35**, 673-695.

Van Zee E.H. and Roberts D., (2001), Using pedagogical inquiries as a basis for learning to teach: prospective teachers' reflections upon positive science learning experiences, *Science Education*, **85**, 733–757.

Yerrick R., Ross D. and Molebash P., (2005), Too close for comfort: real-time science teaching reflections via digital video editing, *Journal of Science Teacher Education*, **6**, 351–375.