Participatory Action Research within Chemical Education

Ingo Eilks & Bernd Ralle

University of Dortmund, Germany

Participatory Action Research is recommended as a method for conducting research within chemical education. This can provide research on curriculum development and improved teaching strategies with a well-founded methodological framework. The objective is to establish an accepted methodological foundation for education research, to fit curriculum development better to the needs of practice, to ensure that research is of value for practical use, and thus to close the gaps between curriculum development, empirical research and teaching practice. The main aspects of the research strategy are discussed here. In addition, initial experiences that were made using this method are presented. They refer to a project that was designed to develop new, more efficient approaches to teaching the particulate nature of matter in lower secondary school chemistry.

Introduction

The academic field of chemical education lies between the fields of educational science and chemistry. In Germany, a controversial debate exists about whether it is more closely related to chemistry or to education. The objectives of and the methods applied by researchers in these fields are very different. They range from empirical research on learning processes using classic methods of the social sciences, to research in the means of creating new school relevant experimental tasks for students to integrate new discoveries from chemistry into education.

Thus, chemical education research is multi-facetted. In order to provide the discussion on chemical education research with an underlying structure, Eilks & Ralle (2002b) suggest defining the two central fields, i.e. *empirical research on learning processes* and *curriculum development*, as *pure* and *applied research* respectively. Although both fields are related to each other, and they do partially overlap, and in some cases are even combined, they can be differentiated from one another as follows:

- *Pure chemical education research*: Research with the primary objective of obtaining empirically based insights into the processes of learning chemistry. Pure research applies empirical methods from the educational sciences.
- *Applied chemical education research*: Research with the primary objective of inspiring changes in teaching practice using a variety of activities, including the development of new curricula, teaching strategies and materials.

Applied research within chemical education, using this definition, was the predominant type of research being conducted at German universities in recent years.

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Nevertheless, a debate about how best to conduct research within this field never took place. Quite to the contrary, it has been repeatedly questioned whether or not work done towards curriculum development, and for new teaching strategies and materials, should be considered ‘research’ at all (e.g. Gramm 2000).

Thus, 'didactics of chemistry' groups at German universities are repeatedly asked to legitimise themselves as researchers if their work focuses exclusively on curriculum development. This discussion is closely related to questions about which research methods and strategies should be applied in this field. Curriculum development will not be viewed as legitimate research unless it applies methods that are recognised in other fields. In order to recommend an appropriate research methodology, a discussion about the faults in current research practice is helpful. These can be summed up in three points (Eilks & Ralle 2002a and b):

- Proposals for designing better or alternative chemistry lessons are often not based on the outcomes of empirical research.
- New concepts for teaching and learning chemistry have often not been sufficiently evaluated using empirical methods.
- Most of the new approaches developed for chemistry lessons have not been implemented into teaching practice broadly and systematically.

On the other hand, some aspects of the practice of pure research within chemical education have also been criticised (e.g. de Jong 2000; Costa et al. 2000; Taber 2001; van Driel et al. 2001):

- The subjects of empirical research are often not oriented towards the primary needs of practice.
- The results are not sufficiently recommended and prepared for use in curriculum development and teaching practice.
- The results of purely empirical research are often not well accepted by practitioners, especially if the research was conducted without involving authentic classroom practice and/or without the strong involvement of the teachers.

So, in the future, in our opinion, the following aspects of chemical education research should receive more emphasis (Eilks & Ralle 2002b):

- Pure empirical research should focus more strongly on the needs of practice.
- Applied research should more actively integrate the results from pure empirical research.
- Applied research must choose acceptable research strategies. These strategies must comprehensively ensure the plausibility, credibility, relevance and importance of the results. Reports and papers on research done in this field should include a sufficient discussion about the methodology used in development and evaluation.
- Curriculum development should be systematically related to teaching practice, and teachers’ circumstances and needs. Thus, teachers should be systematically integrated into the research process. In this way, teacher training can become an integral part of research.

- Dissemination and implementation of the results should be an integral part of chemical education research, regardless of whether it is pure or applied research.

The approach of Participatory Action Research might lead to research projects that integrate both pure and applied research within chemical education. It also has the potential to help researchers achieve the objectives mentioned above. (In other papers in this book, also van Driel or Valanidis discuss the potential of action research for improvements in this direction and Bulte et al. describe a related research design. Other examples from science education related to this approach are described in Feldman (1996), Parke & Coble (1997), Bencze & Hodson (1999), or Haigh (2001)).

Participatory Action Research as a strategy for applied research within chemical education

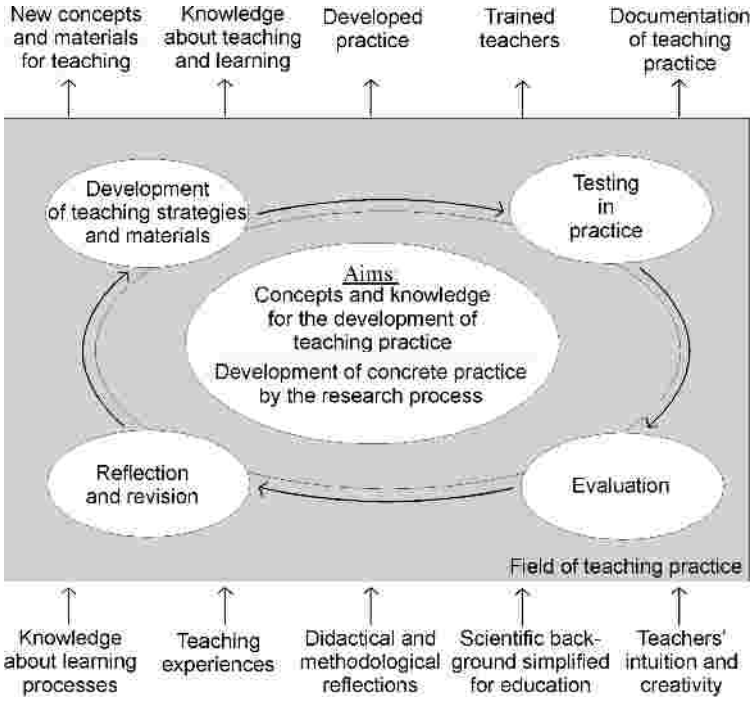

Fig. 1: Participatory Action Research within chemical education

Objectives

For applied research within chemical education, the main objectives are the development, documentation and implementation of new or improved teaching concepts and materials. The goal is to develop teaching strategies and materials that can potentially improve practice in as many learning groups as possible. Thus, we do not consider Action Research approaches that are practitioner-centred to be appropriate. The differences between practitioner-centred approaches and approaches based on the classical ideas of Lewin have been discussed (e.g.) by Maruyama (1996). We consider approaches that focus more on the research questions of the external researcher and on obtaining more generalised results to be more appropriate than approaches that strive to improve practice within individual groups.

Participatory Action Research seems to be the most appropriate method (e.g. Whyte et al. 1989; Wadsworth 1998). The objective of this method is to derive results that are widely applicable and based on empirical observations of teaching and learning. Even so, the method also intends to improve the teaching of the practitioners involved. That means that curricula are developed for real-life practice situations in individual learning groups and that the teachers who are involved are trained as a part of the research process. Therefore, the primary objectives of the research process are (see Fig. 1):

- the development of teaching strategies and materials that can improve teaching and learning practice, and the evaluation and dissemination of said strategies,
- the attainment of general knowledge about learning processes and teaching practice,
- the reduction of deficits in concrete teaching practice among teachers involved in the process,
- the in-service teacher training of the involved practitioners, as pertains to their awareness of how well they work and improving skills in curriculum development and evaluation of teaching practice,
- the documentation of teaching practice and experiences.

Researchers and practitioners

Action Research is generally described as a co-operative process between practitioners and external individuals, in this case teachers in classroom practice and chemical education researchers from the university. As a matter of principle, the persons involved have equal status and they all contribute to all of the decisions made during the research and development process. The objective is to come to a consensus within the group and to agree upon a common strategy. But, in the end, any decisions concerning changes in concrete practice are left up to the respective teacher. Although both groups are of equal status, it is helpful to think of them as having different roles (cf. Altrichter & Gstettner 1993). The external researchers focus on organising and co-ordinating the research process, developing and justifying the changes in practice and evaluating their effects. The teachers concentrate their efforts on translating the new methodological elements into their practice and testing the changed approaches (Fig. 2).

In this type of team, it is important to remain aware of these different roles. Altrichter & Gstettner (1993) warn that there is a risk that the external researcher can strongly dominate the team. This risk exists because of the widely held belief that theoretical knowledge is of ”more value” than practical experiences, and it can also be due to the implicitly hierarchical relationships between universities and schools: "The abstract concepts of 'theory' and 'practice' were often too easily personalised in the sense that professional researchers stood for 'theory' and practitioners for 'practice'. Thus, a hierarchy was established which made learning in the other direction more difficult: e.g. the development of the researchers' theory and practice through theoretical and practical critique by practitioners" (Altrichter & Gstettner 1993, p. 344).

But, the awareness of the different roles also provides an opportunity to learn. The tension between the different individuals involved makes it necessary to discuss their different points of view. This can lead to more awareness of and reflection about the relative values of theory and practice and the different viewpoints of teachers and external researchers. This might help to generate more understanding between these groups. In general, Action Research is believed to have potential to break down the barriers between schools and universities (Noffke 1994).

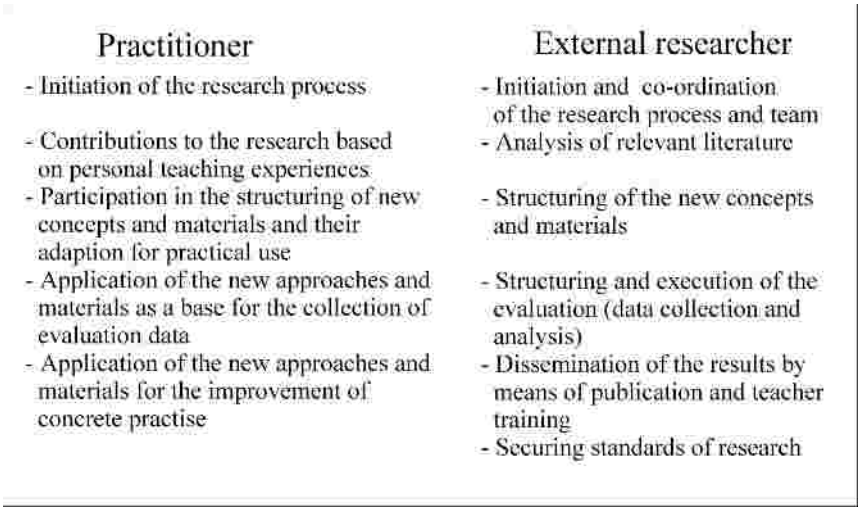

Fig. 2: Roles of practitioners and researchers

The research team should always be open for the integration of new practitioners. By expanding the research team step by step, a wider array of teaching experiences is made accessible, and more practitioners are influenced by the research. The more practitioners involved, the higher the likelihood that the results of the research will be disseminated within the schools.

Starting point, cyclical procedure and the three stages of development

The research process is initiated when deficits in teaching practice or in empirical research are observed. Research is intended to find methods for eliminating or reducing teaching deficiencies. But the research objectives discussed above are meant to solve problems of general interest. So, the research should be designed such that it deals with deficits that occur in a broad range of teaching settings and learning groups, and not just in one classroom. At the start, a broad discussion between researchers and teachers and a thorough analysis of the relevant literature should be used to determine whether or not the question is of general interest. There are several questions that are central to this analysis: 1. Have similar and/or related problems been documented? 2. Are results from empirical research available? and 3. Have attempts been made to reduce these deficits? This analysis of the existing research on teaching and learning processes should be conducted cyclically and continuously, i.e. when new material is available it should be evaluated and compared, and the research objectives should be altered as needed. This analysis must be done with the practitioners to ensure that the collected data is relevant with respect to the problems

that exist in concrete practice. This ongoing analysis should be conducted in parallel with the whole research process. In order to structure, improve, test and evaluate practice, it is essential to gather background information from scientists and scientific literature, and to learn about and from the experiences, intuition and creativity of researchers and practitioners alike (Fig. 1).

Every kind of Action Research is described as being cyclical. This is one of the main differences between action research and more conventional research designs (Wadsworth 1998). At the start, new teaching approaches are designed that are then used and tested with the objective of improving practice in the testing groups. So, first provisional teaching concepts are designed. These initial designs are used and tested as early as possible to see whether they have the potential to solve problems in teaching practice. The external researchers and the teachers plan the implementation of the curricula together. The process of planning as a group is important, because it ensures that the designs are compatible with the needs of everyday practitioners. Planning together also ensures that the tests of the teaching concepts and the evaluation are being conducted simultaneously by all of the teachers. The inclusion of practical teacher experiences is one of the main differences between the Participatory Action Research method and the way that curricula are normally developed. In most cases external institutions prepare finished teaching concepts that are not evaluated by practitioners until the structure and design have already been finalised.

The objective is to improve practice step by step with each cycle of development (Fig. 1). In order to do so, each of the cycles must be analysed and evaluated. The evaluation should take the perspectives of all of the participants (teachers, students, and researchers) into consideration. On the other hand, the curricula are developed within a practice setting and using close cycles of development and testing. For this reason, evaluation tools and strategies should be chosen that are appropriate for the setting (e.g. Bodner et al. 1999). They can be adapted during the research process as needed, and they should be further improved during each cycle of development. Several methods are suitable, e.g. standardised questionnaires, documentation of verbal feedback, group discussions among the practitioners, or sample interviews with the students. These methods can also be supplemented with an evaluation of the teaching materials that were developed.

It has been suggested, e.g. by Bodner et al. (1999), that classical strategies that apply a quantitative understanding of evaluation are not appropriate for, at least this kind of, curriculum development. That is because there are far too many influencing factors, and the researchers and practitioners are personally involved. A qualitative and interpretative paradigm is more suitable for this type of research. The validity of the interpretations can be tested and/or confirmed during discussions between external researchers and practitioners. The criteria defined by Altheide & Johnson (1994) can be used as a guideline: plausibility, credibility, relevance and importance. As opposed to classical procedures, the practical experience of the teachers, and their assessment of their teaching success, plays an important role in evaluating the research. The teachers have a permanent influence on the research process (e.g. Noffke 1994).

If the evaluation indicates that the curriculum changes were successful at reducing teaching and learning deficits, the development and research process can be continued in a new phase that will potentially lead to even more improvement. The newly developed research phase should try to determine the reasons behind the deficits, and the impact of the changes that were made during the previous round of research. The intention is to obtain general, yet relevant background information. With each cycle, the improvements in the teaching concepts should be more significant, better thought out, and more broadly applicable.

Based on our experiences, it is helpful to define three phases that are similar to those described by Stang (1982). Each of these three phases can consist of several cycles of development, testing, evaluation and reflection (Fig. 3).

The first phase is carried out with a small team. In this phase, the problem is considered, the relevant knowledge is analysed, and first provisional concepts are developed. The concepts are then tested in single groups in order to decide whether the planned interventions have the potential to improve practice.

In the second phase, a team is created that consists of a group of teachers. The integration of teachers, who were not involved in the first phase, is the most important aspect of this phase. Their inclusion broadens the field of practice and also provides impartial feedback on the results of phase one. While working to motivate the teachers and explain the legitimisation of the new approach, the teachers provide feedback and the researchers are forced to rethink their assumptions. During the second phase, most of the work entails planning for changes in teaching practice, carrying them out and reflecting on the results.

In the third phase, the main task is the dissemination of the results into practice. This also requires an evaluation of the new teaching methods and materials to determine whether or not they have been documented well enough that external practitioners can apply them without additional training.

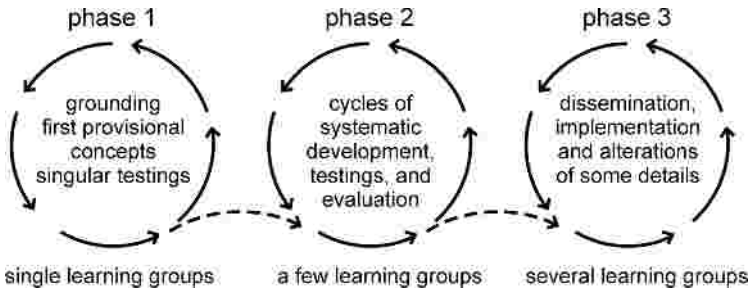

Fig. 3: The three phases of the development process

The term “Action Research” implies that it is necessary to document and report the work and results continuously while the research process is taking place. These types of reports can help to improve practice outside of the research team, even if they only mention problems or deficits that have arisen during the research process. Therefore, the discussions and interpretations should be well documented. The documentation may also include a description of the background and individual interests of the

practitioners and researchers (Dickson & Green 2001). In the end, the reader will decide whether he or she feels that the described approaches are authentic, relevant and credible, and whether or not they would be beneficial for their individual practice (Mayring 1999).

Ethical issues

Action Research is carried out in a social setting with the objective of improving practice. Hence, it always has an influence on practice and the persons involved. When using the procedure described above, this effect is especially significant if the provisional concepts are applied and if they are tested by teachers who are not fully trained in the new approaches. All of the persons involved should consider the influence they have on practice (cf. Tobin 1992). They should ensure that:

- the influences on practice do not inadequately damage or harm any of the personal interests of the teachers or students involved, for example if the students are switching their teacher, class or school.
- it is possible to switch back to the conventional concept if necessary without undue disadvantages for students or teachers.
- the skills taught and the learning objectives of the lessons are at least as valuable as those taught using the conventional method, even though the nature of the skills and information can be different.
- all decisions made concerning changes in practice acknowledge the influences they have on practice.
- all data from real practice is handled confidentially, especially evaluative and assessment data.

Experiences

This method of chemical education research was developed, and has been applied, for about three years now. The model project deals with designing new approaches to teaching the particulate nature of matter more efficiently (cf. Eilks & Moellering 2001; Eilks et al. 2002; Leerhoff & Eilks 2002). It is a co-operative project that is being carried out by the University of Dortmund and several middle, comprehensive and grammar schools in western and northern Germany. The project has now entered into the second phase, and one year of broad testing and evaluation has been conducted.

After several important steps, and at the end of each school year, a broad evaluation took place. An attempt was made to gather opinions on the research from the practitioners, the students and the external researchers using various evaluation tools. The evaluation was designed to determine how well the curricula and methods are accepted, how feasibly they can be used, and how much the students learned (Fig. 4).

In almost all of the cases investigated here, the teachers assessed the teaching strategies, the teaching materials, and the research process, to be of value for their practical use. They felt that the new methods have the potential to reduce the previous

learning deficits. Teachers who later came into contact with the material at in-service teacher training courses, but who were not involved in the study, expressed similarly positive opinions. Both groups characterised the teaching methods as being appropriate for use in practice and as being more feasible than other concepts they were familiar with. The other concepts had been developed without involving classroom practice.

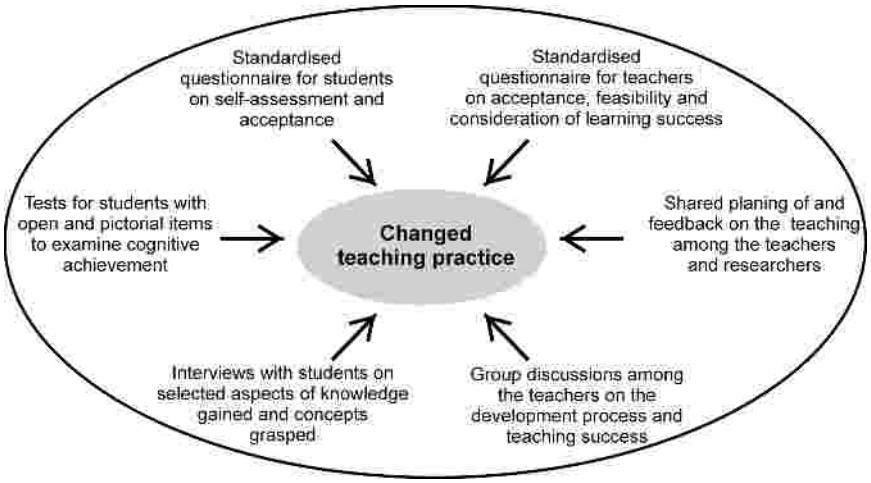

Fig. 4: A possible combination of methods and perspectives

When describing their experiences with the research process, the teachers mentioned that they were now more concerned about improving their practice, that they had learned to better share their ideas and experiences, and that they were now better trained for their professional needs. They pointed out that they were more aware of problems in their practice that were similar to those described in the literature and were now more motivated to change their curricular approaches. They developed a sense of personal responsibility about the need for change and felt that they were co-owners and creators of the approaches that they had developed together. In some cases, the teachers who were involved have actively worked to disseminate the new approaches among their colleagues.

Almost without exception, the students stated that they found the developed teaching strategies and media to be helpful in learning the concepts that were taught. They also felt that these methods could make their lessons more attractive. The integration of the developed learning materials into the lessons was seen as being well tuned, e.g. they required an appropriate amount of work and were at a good level of complexity. The results show that over time, and as more changes were implemented throughout several cycles of testing, the students' level of approval increased. The participants thought that the new curricula also improved cognitive achievement. An evaluation of the cognitive achievements showed that most of the children learned the material well; the teachers all had the impression that the children had achieved a higher level achievement as compared to their previous experiences teaching the same topics.

The most difficult part of the research process may be taking the experiences made with concrete practice and curriculum development, and interpreting what they mean

in respect to general problems in chemical education. Up till now, respective results have been obtained in different areas (cf. Eilks 2002b, Eilks & Ralle 2002b), e.g.:

- *Conventional teaching concepts and their use in science education*: As part of the analysis and reflection of practice in phase one, problems that exist when using conventional teaching approaches were described. Conventional strategies are often not tailored to the needs of students, as has often been demonstrated by empirical research (cf. Eilks & Möllering, 2001). Also, in some cases, the concepts being taught are problematic because their structure is not appropriate for novices (e.g., in the field of introducing chemical reactions). That is the case regardless of the teaching methods used. Thus, the concepts being taught also need to be revised so that they are more feasible to the learning requirements of the students (cf. Eilks et al. 2002).
- *A broader, empirically based understanding of learning*: By combining different evaluation tools and the results of various studies, many conclusions were drawn about teaching and learning the particulate nature of matter. Several problems were identified, and tools were developed so that they could be evaluated. For example, some typical misunderstandings about the use of certain terms, e.g. from the field of matter and properties, were observed. These problems are similar to results described by empirical research in non-German-speaking studies. Now respective results and suggestions for changes in practice to reduce this problems are available also for teaching in German language (cf. Leerhoff et al. 2002).
- *The use of alternative teaching strategies and their influence on students' attitudes towards science lessons*: After comparing data from different lesson topics and from different perspectives, it is clear that the inclusion of new media and new methods of co-operative learning can help to improve students' attitudes toward science lessons. The studies have also demonstrated that by using alternative methods, which focus more on student-oriented and student-active learning, students' non-cognitive skills improve (cf. Eilks 2002a).

All of these results show that there is potential for positive developments in teaching practice and curricular development (see also Eilks 2002b). But, the process of improvement is not over by any means. Due to the cyclical nature of the research, researchers and practitioners have an ongoing opportunity to improve upon what they have learned in each phase. This leads to a deeper understanding, and therefore, in almost all cases, to a sharpened perception, and the recognition of both new and old problems. This process of increasing teacher awareness is at least as important, if not more important, than the other results. The research helps researchers and practitioners to develop a more critical view of learning and teaching. The problems that are recognised during one cycle can become the subject of research in the next.

Concluding remarks

After three years of working with this method, we believe that Participatory Action Research has great potential to improve chemistry education. The research process

leads to teaching strategies and materials that can greatly improve teaching practice. The teaching methods are tailored to practice, because they are developed in practice and with teachers. Practitioners who were not involved in the research process have confirmed that the lesson plans are very authentic and relevant. Also, the practitioners were influenced by the process, and after becoming aware of their deficiencies, often went on to change their methods. The research process worked in this sense as in-service training. The teachers were more aware of how they teach, and their skills in developing new methods and gathering feedback improved. The research process also results in documented practice experiences and empirically based findings on more general aspects of teaching and learning. Teachers also found these results to be authentic and helpful.

However, on the other hand, Participatory Action Research, as defined here, is surely not a cure-all for every problem in teaching practice and curriculum development. When designing a research project, the activities and the evaluation tools must be chosen individually and as appropriate for each project. There are still many unanswered questions and challenges regarding the goals, interpretation and methodology of Action Research (Noffke 1994). Projects should be designed to ensure their validity and reliability, and researchers should include safeguards so that they do not end up with results that are solely of personal interest to the teachers involved.

Hopefully, future results from this and other research projects will further demonstrate that Participatory Action Research can help to greatly improve chemical education.

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