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Mixed-age chemistry classes: conception and realization of inter-grade experimentation sets in the context of the reform pedagogy according to Maria Montessori

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Abstract

In the course of the restructuring of the German school landscape over the past 15 years, concepts have become established which, on the one hand, require a different approach to the heterogeneity of the student body and, on the other hand, demand the teaching of independent and more complex learning and work. A model that integrates all these pedagogical elements is represented by the approach of mixed-age teaching, which is already being implemented primarily in the primary level of the German education system. The environment of the mixed-age learning group represents one of the core elements of Maria Montessori's reform pedagogy. Here, students of three grades learn together, according to the 'principle of naturalness' postulated by her. Another essential feature of this pedagogical approach is the special learning materials provided by the teachers. These are geared to the students' self-acting, in the spirit of Montessori: 'Help me to do it myself!'
The primary objective of this work included the conception and realization of learning and experimentation sets for mixed-age teaching in chemistry, which should be equally suitable for students in grades 7, 8 and 9. With this in mind, an exemplary set on the subject of 'Acids & Bases' was created. The experiments contained in the set are intended to meet the requirements of mixed-age learning (especially content fit for all three grades) as well as the essential aspects of reform pedagogy according to Maria Montessori, e.g., internal differentiation, stimulating and self-explanatory material.
For this purpose, theory-based criteria for the design of age-heterogeneous experiments were developed, which were supplemented by criteria from qualitative interviews with teachers and students. The experimental design was tested at the Montessori School Jena. The final step was a qualitative survey of the participating students. The project provided an insight into the suitability of the materials for age heterogeneous learning contexts, as well as for the exposition of important design criteria.

Keywords: *reform pedagogy, Maria Montessori, mixed-age classrooms, acids and bases*

1. Introduction

Following the results of school performance studies such as TIMSS (***T**rends in **I**nternational **M**athematics and **S**cience **S**tudy*) in 1997 or the PISA (***P**rogramme for **I**nternational **S**tudent **A**ssessment*) shock in 2001, the German education system has repeatedly become the focus of political and social debate. Among other things, it became apparent that a considerable number of students in Germany have an insufficient ability to connect different knowledge areas. As a result, it is ostensibly more complex questions and problems whose successful processing and solution cause difficulties for the learners. [1] Based on such a realization, the call for reforms in the German education system became louder and louder and the school landscape in Germany has changed visibly over the past 15 years. In connection with these structural changes, concepts have been established which, on the one hand, implement a changed approach to the heterogeneity of the student body and which claim to teach independent and more complex learning and work. In addition, they also strengthened the practice of internal differentiation to a great extent and thus allowed for more intensive support of the individual development of students. A model in which all these pedagogical elements are integrated is represented, for example, by the approach of **mixed-age teaching**, which is already implemented mainly in the primary level of the German education system. At the Montessori School Jena, this form was increasingly integrated into the science lessons starting in the school year 2017/-18, in the form of the three-year mixture of grades 7, 8 and 9, which is based on the Montessori pedagogy.

2. Mixed-age teaching in the context of Maria Montessori's reform pedagogy

The term is understood to mean '[…] *an alternative form of school organization in which students are not grouped into classes by year, but rather different age groups are integrated into one class.*' [2] In this context, three different forms can be differentiated (Fig. 1):

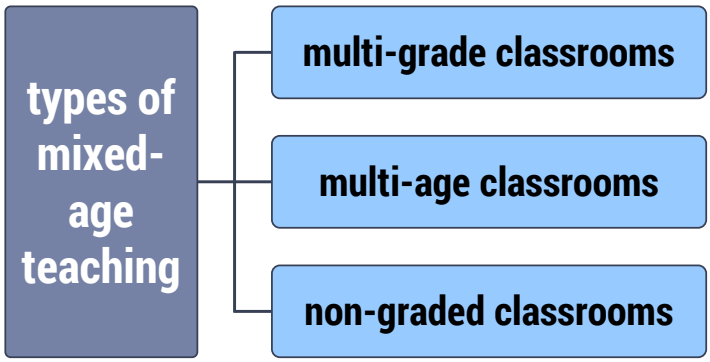


Fig. 1: Types of mixed-age teaching, according to KUHL et al.

Multi-grade classrooms are basically understood as the teaching of different grades together (in contrast to single-grade classrooms). According to KUHL et al., the establishment of these classrooms is essentially based on organizational considerations. **Multi-age classrooms**, on the other hand, are set up for pedagogical reasons with a view to promoting individualized learning processes. The 'highest form' of these forms, however, are the **non-graded-classrooms**. The structure of such schools is not based on the age of the children, but on their individual performance levels. Flexible groupings in the sense of performance-homogeneous learning groups are created. At this point, however, it must be pointed out that these terms are usually not used in a clear-cut manner, and that they cannot be regarded as independent of each other. The environment of the mixed-age learning group represents one of the core elements of MARIA MONTESSORI's reform pedagogy (Fig. 2). Here, students of three grades learn together. The three-age mixture typical is based on the 'principle of naturalness' [3] it describes. MONTESSORI sees the age mix in the school as a reference to the child's natural habitat, but the age-rich grouping as a departure from it. [4]

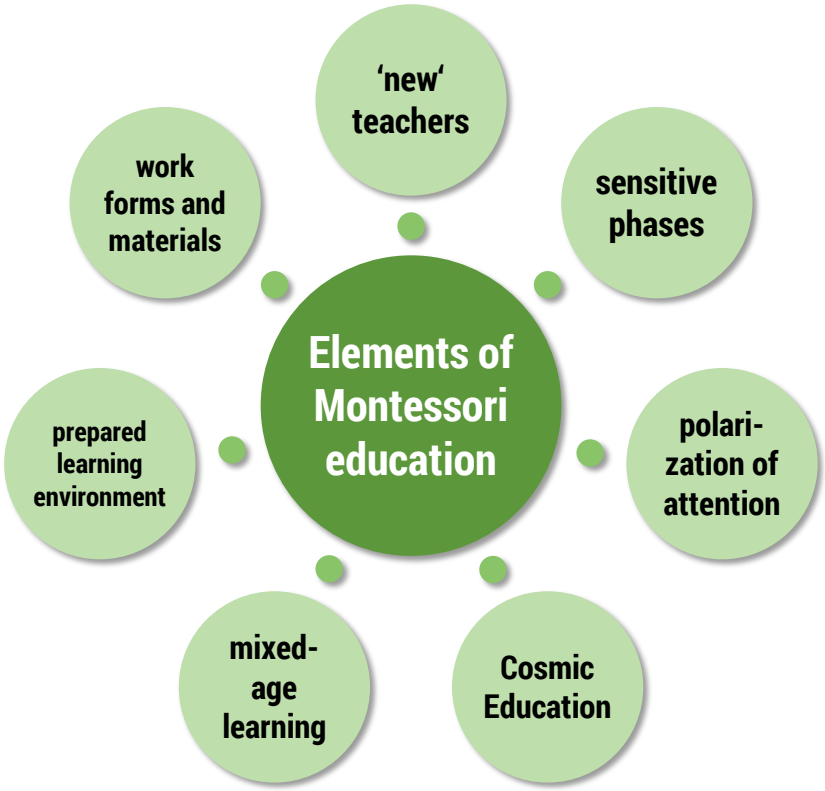
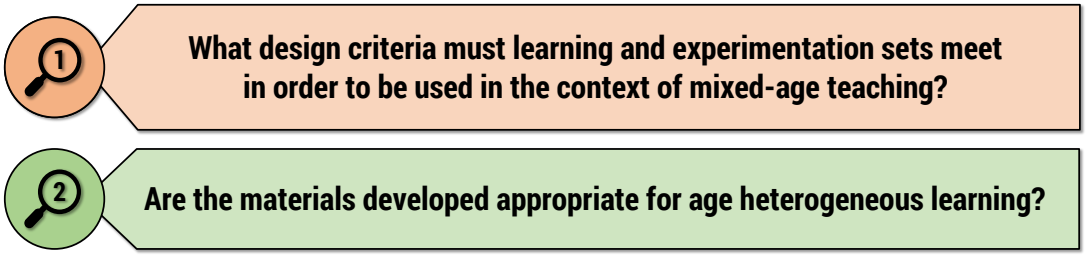


Fig. 2: Central elements of the reform pedagogy according to MARIA MONTESSORI [5]

3. Research interest

The present work supported this process in chemistry class with regard to the following aspects: A first part dealt with the presentation of basic construction criteria for learning and experimentation sets in the context of age heterogeneous learning. Based on this criteria catalogue, derived from theory and supplemented by statements of science teachers, such a set was developed as an example and placed in the focus of further investigations. The central goal of the subsequent testing and evaluation of this set on the topic of "Acids & Bases" by students between the ages of 13 and 16 was to examine the suitability of this material regarding its use for promoting and optimizing chemical learning processes in the context of mixed-age teaching in lower secondary school. In summary, two central questions can thus be formulated that represent the specific research interest of this thesis:



4. Study design and methodological approach

Basically, the format of this work followed the design-based-research approach, according to which a practice-oriented problem or question is answered in a theory-guided way. [6] For this purpose, it was necessary to establish interdisciplinary references between educational and scientific fields in the work. In this context, educational basics were coupled with subject-specific content and subject-didactic methodology. Due to the explorative character of the questions raised, the approach of this work can be assigned to the tradition of Qualitative Research Methodology. In this context, a process was realized that comprised a total of four central phases, alternating between theoretical-curricular and qualitative work steps (Fig. 3):

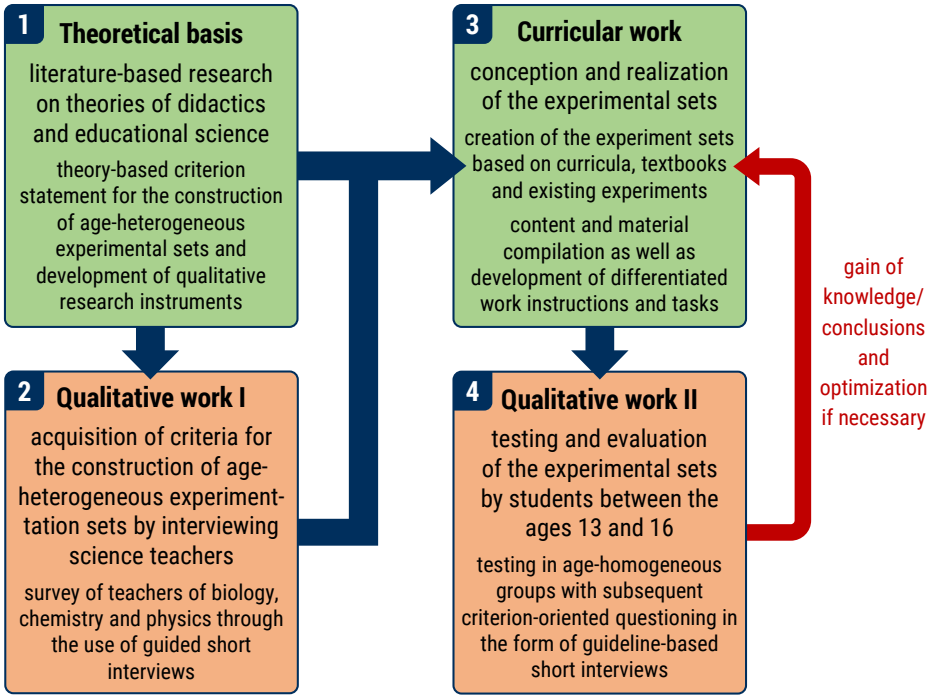


Fig. 3: Methodical procedure and investigation process

The collection of the required evaluation material was realized the help of specially designed guided short interviews, which were based on the work of SCHECKER et al. [7] regarding their structure and development and on the quality criteria according to MAYRING with regard to the evaluation process.

5. The learning and experimentation set ‘Acids & Bases’

Conceptually, it should first be mentioned that the learners are granted freedom so that they can actively shape their learning process. This includes, for example, the free choice of the social form as well as the determination of the sequence in which the subject areas or individual modules are worked on. A module overview available for each subject area serves as an orientation aid. On the other hand, there is an obligation to document and hand in the contents of each individual module. The exemplarily developed subject area is divided into a total of four modules, each with a thematic focus (Fig. 4):

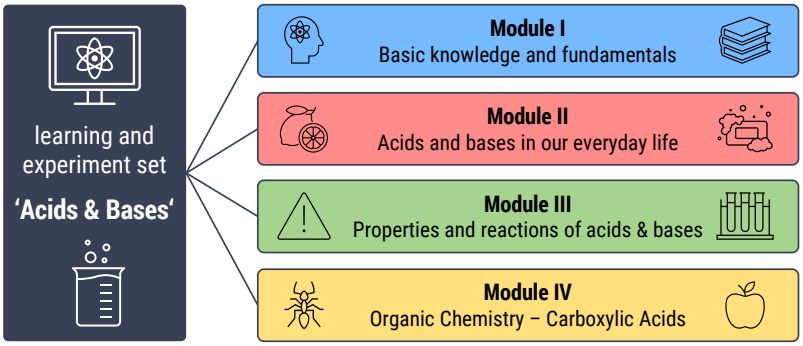


Fig. 4: Structure of the designed learning and experimentation set ‘Acids & Bases’

These are in turn subdivided into individual stations, which are either of a theoretical or experimental nature. The curriculum for chemistry teaching in Thuringia forms the basis for the content to be worked on in the stations. [8] In the case of the present set, Module I is a purely theoretical unit, whereas the remaining three modules consist exclusively of experiments. The work instructions generally have a bi-differentiated character, which is applied in the form of a traffic light system (red, yellow, green) for the individual requirement levels (I: reconstruction, II: application, III: transfer). The instructions are basically written on the requirement level III (red). Consequently, the students are required to deal with this level first. In case of difficulties, the learners can use a tablet or their smartphone to scan the QR codes printed on the work instructions. After this process, a PDF file is opened on the corresponding device, which contains differentiated instructions, depending on the level of difficulty, with more concrete instructions, hints, and pictographic experiment setups.
In this way, students should be able to reflect on their level of knowledge and ability and choose differentiated instructions according to their individual learning level. After an experiment has been carried out, it is finally evaluated, usually in the form of a worksheet or a report, in a task- or content-oriented manner. For this purpose, the learners are also provided with assistance in the form of literature references for research or in the form of learning videos, which are also QR-coded and can be called up as needed. On the one hand, this principle is intended to ensure that the competency goals anchored in the curriculum are achieved. On the other hand, the students should be able to choose the depth of processing and to contribute their own ideas and approaches to solutions.

6. Results and outlook

Based on partial transcripts from the guided short interviews with the teachers, a comparison could be made with the theoretically determined design criteria. Synthesizing these results, three central fields with a total of nine criteria were identified (Fig. 5):

Fig. 5: Identified construction criteria for designing mixed-age learning sets

On the one hand, these factors represented the starting point for the curricular development work. On the other hand, they also served as the basis for the development of the intervention modes for the evaluation interviews with the selected students. The overall transcripts of the short interviews that were also used, which were produced from these discussions, allow us to conclude that the material developed is suitable for use in inter-year science lessons. Superficially with regard to structural and material aspects, the results give reason to believe that the present system can be retained and, if necessary, applied to further thematic sets. In summary, however, it must also be stated that a primary optimization of the tasks with regard to a higher level of challenge for older learners appears to be necessary. Furthermore, the production of more test-specific learning videos should be increasingly realized. On the basis of these results, it is conceivable to support the further development of teaching in the subject chemistry at the Montessori School Jena by the conception of further sets, which can be justified spiral curricular or project-oriented.

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