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The use of auditory media as mathematical language support in elementary classroom practice

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This paper focuses on the use of auditory learning material as specialized language support in elementary classroom practice. Radio features, with their relevance in everyday life, can serve as a natural auditory learning material for children. Thus, we investigated various applications of radio resources in teaching practice. The aim of this research is not only to investigate what a profitable use of auditory material would look like, but also to investigate the effects of such practice on the learning procedure in general and specifically on the development of the school register. First results show that auditory media can indeed be effectively implemented in teaching practice as a provided linguistic model and reveal just how these effects look like.

Educational media, aural learning, radio, language acquisition, visualization.

Cooperation with a Radio Station

In 2015, the Department of Mathematics Education at the University of Giessen started a project in cooperation with a regional radio station *hr2 – Hessen Radio for Culture*. Within this project, a series of radio broadcasts on mathematical topics for the primary school level was developed – called *Kinderfunkkolleg Mathematik*¹, as well as accompanying material for use in elementary classrooms. More information about this can be found in the proceedings of CERME11 (Peters, 2019). Based on this project, research on innovative classroom practices was started that integrate auditory learning material as a central element to find out what a profitable use of such material could look like. Furthermore, the effects of auditory media as a specialized language support in mathematics education were investigated. In particular, the question was asked how auditory material can stimulate the development of the school register as a linguistic model.

The Potentials of Auditory Media in Mathematics Education

According to Mayer's memory model (2009; see also Baddley, 2007), visual and auditory information are processed in two different sensory channels. Using auditory media as learning material reduces the sensory impressions on the visual channel and focuses the sensory impressions on the auditory channel. Hence, the auditory channel becomes more tasked and can be trained more. Purposive use of auditory media can supply the listener with repeated and specific auditory input and thus foster the processing of information in the auditory channel. Based on this, the Purposive use of such media can furthermore foster the development of language (Niehbuhr-Siebert & Ritterfeld, 2012). Building up on the memory model, the Cognitive Load Theory by Sweller (1994) says that the capacities of the working memory are limited and should not be exhausted by extrinsic factors like too many animations or reading. Reading difficulties can exhaust the working memory and lead

¹ www.kinderfunkkolleg-mathematik.de

to not understanding mathematical content as well as not being able to solve mathematical tasks. Keeping mathematical concerns in the center of learning processes while reducing extrinsic factors is one important principle of auditory learning. For this reason, Rink and Walter (2019) are using text-to-speech technology (TTS) to support learners with difficulties in the written language while solving written tasks. Thus, it can be stated that auditory support can aid children with reading difficulties to understand mathematical contents and tasks without the need of having to read coherently and extract the meaning. The absence of a visual representation of the subject can be a learning potential as well. Children are cognitively challenged to develop their own visual representation of what they heard. When working with auditory media of mathematical content, students have to develop visual representations of e.g. mathematical concepts, geometrical shapes or figures (Peters, 2021).

In pandemic times, we also made first experiences of using auditory media in distance learning and developed accompanying material for homeschooling parents as well as for teachers that needed educational material suitable for distance teaching and learning.² There are a lot of good radio resources that can be found online and be used as educational material. So, good auditory learning material is very easy-to-access and all it takes for a teacher to get it to his students in distant learning is to send them a link. A very easy and useful tool - if implemented intently and well-thought-out i.e. if criteria for choosing and using auditory media are considered. Those criteria will be explained below.

Potentials of Auditory Media Concerning Language

One of the most obvious potentials of auditory media is the development of active listening skills. Such competence is a primary requirement for education, but it is seldom supported or even trained (Pimm, 1987). Another potential can be described by looking at the *Model of Orality and Writteness* (Koch & Oesterreicher, 1985). In this model, auditory learning materials can foremost be categorized as being medial-oral. If they are designed for children, they are also more likely conceptual-oral because they utilize everyday language and explain in a child-orientated and situational manner. Still, they use mathematical terms and phrases of educational language. Thus, they are also characterized through conceptual-textual elements and – in the right learning environment – can be able to lead children from orality into writteness. At best, this can possibly guide listeners to use mathematical terminology in orality as well as in writteness. This makes them act in a more conceptual-textual way.

Prediger and Krägeloh (2016) are referring to a model of three registers relevant for mathematical learning (everyday register, school register and technical register). School register is an important factor for successful learning in mathematics, as it is a shared language basis and helps with explaining, describing and justifying (Götze, 2015). However, children do not bring this type of language to school with them. It must be learned. Thus, linguistic models are needed to develop educational language and to fill terms with representations. These linguistic models are scaffoldings

² <https://www.kinderfunkkolleg-mathematik.de/unterrichtsmaterial>

onto which children can lean (Gibbons, 2002). Here, auditory educational material could be a profitable addition.

Criteria for Choosing and Using Auditory Media

Exploiting the potentials of any media starts with choosing “good” media. Considering auditory media, conditions of success are necessary in order to support an active processing of what has been heard and then to achieve an output that is correct in terms of content and language. Thus, criteria for student-friendly audio offers must be established as well as methodological notes for good embedment in classroom practice. For example, listening to auditory resources should be combined with (listening) tasks to support selective and comprehensive listening. Also, opportunities to document results should be given. In accordance with the segmenting principle (Mayer, 2009), important sequences should be cut and listened to in segments. Those segments can then be repeated and talked about to make sure the brief acoustic representations are understood by every student. By these means, not only an effective use of auditory media in general but also specialized language support can be ensured.

As there is no visual representation of the subject given by auditory media, verbal explanations in such media need to be very accurate. While working with the production team of the radio station, the importance of a deep reflection and good structuring of the mathematical content became very clear. Verbal explanations in auditory media must also counter the fugacity of spoken language through e.g. linear representation, repetition or sound effects. With those criteria kept in mind, teachers will firstly be able to choose good auditory media for use in mathematics education. And secondly, they will be able to develop teaching concepts in which auditory media serves as transfer of mathematical knowledge, as stimulus in the sense of educational reduction and as language support for developing the academic register.

Methodological Approach

Following these concepts, my research can be focused on the evaluation of the use of auditory media for mathematics education in various settings – particularly regarding possible learning effects. Thus, my research issues can be stated as follows:

RQ 1: How can auditory material support mathematical understanding as well as the development of school and technical register?

RQ 2: What could a profitable use of such teaching concepts look like?

Building on the knowledge base described above, two teaching units consisting of four lessons on the topics *The House of Quadrilaterals* and *Probability and Random Experiments* were examined. In both units, auditory media was used as the central knowledge-imparting medium - the radio features *Wann ist ein Spiel fair?* (When is a game fair?)³ and the radio feature *Wer wohnt im Haus der Vierecke?* (Who lives in the House of Quadrilaterals?)⁴. The teaching units were carried out in two

³ <https://www.kinderfunkkolleg-mathematik.de/themen/wann-ist-ein-spiel-fair>

⁴ <https://www.kinderfunkkolleg-mathematik.de/themen/wer-wohnt-im-haus-der-vierecke>

fourth-grade classrooms. The lessons were videographed, transcribed and categorized using the qualitative content analysis according to Mayring (2015). To develop the aspects of interpretation, the categories, as near as possible to the material, the procedure of inductive category development (Mayring 2015) was used to analyze the data with the software MAXQDA. After formulating a criterion of definition based on the theoretical background and the research questions, categories could be developed which determined the excerpts of the textual material considered for more detailed analysis. In this study those categories are the aspects of mathematical learning as well as the aspects of register development (RQ 1). All of the collected data was worked through and categories were deduced as well as revised in various steps. The detected categories were reduced to main categories and categories relevant to the research issues described above were determined. Subsequently, a selection of scenes for the detailed analysis was made from those relevant categories. Those scenes were interpreted in detail in the sense of interaction analysis (Krummheuer/ Naujok, 1999) to examine the specific research subject and to interpret not only the research itself, but also the specific situation of investigation – between the interaction partners and within their interaction. All of the radio features from the *Kinderfunkkolleg Mathematik* are of 10-12 minutes length. The features are often built around a story line which includes a mathematical problem or situation and involve speakers as well as protagonists that use school register and mathematical terms to confront children with new terms in a playful way. The overall aim of the units is the development of concepts like *fairness* or *the house of the quadrilaterals*, while the linguistic aim is the understanding and the use of important terms that are presented by the radio feature. Those aims work together: language development can help to develop the concept. Working with the auditory media, the classes begin to listen to the first parts of the radio features. In class conversation, students repeat the content of what was heard and discuss the respective mathematical problem. Then, they imitate experiments or work on tasks and problems they heard about in the radio feature. In between those steps, the teachers present more parts of the radio feature and a lexical storage (posters with sentence phrases and guidelines for formulations as well as the necessary vocabulary) (Erath et al., 2021) is collectively developed based on the content of the radio feature. The units also involve tasks in which the students have to transfer their acquired knowledge whilst using the structures of language and reasoning they had been offered and trained while working with the radio feature.

Mathematics Register Acquisition (MRA)

To evaluate the teaching quality and the effectiveness of the use of radio resources in those teaching units, the *Model of Mathematics Register Acquisition* will be of help (Meaney et al., 2012, p.199). The MRA-model is divided into four stages: The first stage is *Noticing*. In this stage, teachers introduce new terms or expressions, use them frequently and then encourage students to using them as well. The second stage, *Intake*, describes the process of understanding. Students start to explore and work with the new terms. In the next stage titled *Integration*, testing, feedback and modification takes place. Students have a good understanding of the new term and are responsible for using it, but might be supported or reminded of their knowledge by the teacher. In the last stage, *Output*, there is a fluent use of the new terms. Teachers do not need to support, but should provide activities where the use of these terms would arise naturally. Auditory media can be of use in the first two stages. It

can be used to introduce new terms and to repeat them frequently in the stage *Notice* and can serve as a linguistic model in the stage *Intake*.

First Findings

Initial observations of those interactions showed that students were highly concentrated while listening to the radio features. It can also be stated that nearly every student was able to correctly repeat the things that have been heard. If anything was unclear, it was easy for the teacher to repeat a certain part of the radio feature. This way, auditory material can counteract transitory learning and be a relief to the teacher as instructions and knowledge are proportioned between him and the auditory learning material.

The qualitative content analysis led to the identification of twelve categories which could be subsumed into three main categories:

- Mathematical-conceptual aspects
- Aspects of language acquisition
- Aspects of media didactics

Examining the relative frequency of occurrence of these categories showed that the aspects of language acquisition make up a significant proportion of the collected data. Thus, further in-depth examination of this area should be of main interest. On the basis of the quantified data and with a view to the research issues, a well-founded selection of transcript excerpts – mostly from this main category – was made for a subsequent detailed analysis in order to examine the influence of audio media more closely. The interaction analysis (Krummheuer & Naujok, 1999) then enabled a deeper insight into individual processes of technical language acquisition. Detailed analysis of interactions showed e.g. that the combination of listening, repetition of specific sequences as well as conversations and discussions of what was heard were of great support for teachers – especially whilst introducing new terms and developing the lexical storage. In terms of scaffolding, auditory materials served as linguistic models on which students were able to lean on. Furthermore, it has become evident that students demanded the visual level of what is heard (for detailed analysis see Peters, 2020). Although sometimes the teacher asked for something written, students developed a visual representation (e.g. by drawing) to support the visual work they were already doing in their head. Even if they didn't draw something (for example a geometric shape) they developed a mental representation without the help of a given image. This can be illustrated by the following example from the data:

- | | | |
|----|----------|--|
| 01 | Teacher: | So who remembers what they said in the audio about those special quadrilaterals? |
| 02 | Max: | Well, there was the convex quadrilateral where all the corners show to the outside... and then concave quadrilaterals... |
| 03 | Teacher: | Can someone help? What about the concave quadrilaterals? |
| 04 | Lea: | There the corners show to the inside... they are like inside the quadrilateral. |
| 05 | Teacher: | Okay... and how can you picture this? |
| 06 | Lea: | They said something like it's punched inside... |
| 07 | Teacher: | Yes.. Silas? |
| 08 | Silas: | Like an navigation arrow or boomerang. |
| 09 | Teacher: | Great that's correct. Can someone sketch how a concave quadrilateral could look like? Joella? |

- 10 Joella: Well... Maybe like the roof of a house but a roof that is a little bit thicker than normal.
- 11 Teacher: Can you make a sketch on the blackboard?

After this Joella goes to the blackboard and draws the following sketch:



Figure 1: Joella's sketch of a concave quadrilateral

So even without ever having been confronted with the concept of convex and concave quadrilaterals and even with just the auditory (i.e. verbal) information and no image of such quadrilaterals, Joella was able to develop a visual representation of what she heard in the auditory resource. She was confronted with only the auditory information and therefore challenged to listen carefully, understand the explanation of the geometric shape – in form of technical register – and furthermore to make up her own visual representation. This cognitive challenge was clearly initiated by the need of visualization which emerged from the absence of visualization in the learning material. Thus, it can be stated that listening to auditory media without the direct provision of visual support led to a development of representations that was initiated by the learner himself.

Considering the language aspect, detailed analysis of interactions show that in the beginning of the teaching units most explanations of the students could be considered as a form of everyday register. However, during and after working with auditory media there was a visible change towards more school and technical register. At the end of both units (e.g. during the final presentations of their experiments, work or tasks), students did in fact use new mathematical terms and phrases that were introduced by the auditory material. Thus, referring to the MRA model (Meaney et al., 2012), it can be stated that there is a development from the first introductory stage *Noticing* to the second stage *Intake* (the process of understanding) in many of the analyzed sequences. Even the third stage *Integration* (testing and modification through feedback) is reached by many students.

Discussion

Despite those positive aspects of mathematical language development there are some limitations that need to be stated. To reach the stage of fluent *Output* students would still need more support and a longer period of use and training. Here a long-term study would be useful. However, the development from stage one to three – from *Noticing* to *Integration* – indicates an apparent improvement in the students' mathematical expression and understanding over the course of the units. The offer of professional language in (educational) auditory media combined with the absence of visuals, gestures

and deictics (unlike YouTube videos etc.) might be a challenge – but a positive challenge – and represents an interesting opportunity for the development of mathematical language and thinking. In the next step of this study, the use and effects of auditory learning material is to be examined in grades two and six to get a broader view on the various aspects of mathematical learning and language development in different age groups.

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