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Specialized language support in mathematics education through the use of radio resources

Franziska Peters

Justus Liebig University, Department of Mathematics Education, Giessen, Germany

franziska.peters@math.uni-giessen.de

This paper offers insight into my pilot study on the use of radio features for specialised language support in mathematics education at the primary school level. With the help of design research, various possible applications of radio resources as auditory learning material are developed and analyzed. One example is described in this paper. The aim of this research is not only to investigate the effects of auditory material on the learning procedure in general, but also to investigate how auditory material can serve as a supportive language example and as a provided language model. First results show that auditory material can indeed be effectively implemented in teaching practice and reveal just how these effects look like.

Keywords: Auditory learning, radio resources, design science, language support.

Background: 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". This radio station developed, inter alia, a series of radio broadcasts on mathematical topics for the primary school collected level. in the multimedia offering "Kinderfunkkolleg Mathematik" (www.kinderfunkkolleg-mathematik.de). Within this collaboration project, future mathematics teachers developed auditory material for use in mathematics education at the primary level. More information about this first project can be found in the proceedings of the ERME topic conference 2018 (Peters, 2018). In a second project, future mathematics teachers planned teaching units for performance in schools, using auditory educational material as a central element. It was important to interrupt longer listening phases and repeat the segments while giving listening tasks in between. The auditory material could be used as preparation of a topic or as a base for discussions, as well as for explaining and deepening new content or repeating previously covered topics. The units were realised in different schools, reflected on in the seminar, optimized and then turned in. After being corrected and edited, the units were then allocated for the download center of the "Kinderfunkkolleg Mathematik," as accompanying material. Based on this project, I started developing research aims and the design of my pilot study to further research on the effects of radio resources as auditory learning material. The material, used in this study is developed and owned by professional radio authors and producers who received help from experts in our university department.

Auditory learning

In order to research the effects and the use of auditory material, one has to understand how auditory learning is working. According to Baddeley (2007), in the working memory visual and auditory information are processed in different sensory channels. Auditory learning reduces sensory

impressions on the visual channel, so that the auditory channel is required and therefore trained more. Acoustic information is processed through various memory processes. The echo memory saves mostly unprocessed sensory impressions for a short period of time. In a next step, the working memory with its limited capacity decodes and processes the acoustic information. It can also build temporal connections that are necessary for remembering the beginning of a sentence while hearing its end (Leuders, 2011). According to Leuders, an increase in efficiency of the working memory is a training effect. Since the processing of auditory information takes place in the working memory, one can assume that the increase in auditory learning efficiency is a training effect. This is a fundamental trigger for my interest in research on auditory learning materials in mathematics education.

Another important aspect is the Cognitive Load Theory by Sweller (1994), more recently taken up by Rink (2014) for the research on digital media in mathematics education. The Cognitive Load Theory says that the capacities of the working memory are limited and should not be exhausted by extrinsic factors. One of those extrinsic factors is reading. Reading difficulties can exhaust the working memory and lead 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 approach for auditory learning. That's why Rink (2014) uses audio recordings as a support for solving written tasks.

Auditory learning material

As a first function, 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. This, however, does not mean that reading should be replaced by hearing. Auditory support should only be provided if needed.

Another function of the use of auditory material 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). In Germany, education standards for the subject of German language make it very clear: These require, not only the competences of reading and writing, but also speaking and listening. Speaking is required to be consciously organized, while terminology is to be trained and (the use of) language is to be examined. Regarding listening, children are to listen attentively and perceptively, while registering others' statements and constructively dealing with them. Of course, listening also takes place in the form of frontal teaching, but this kind of listening is difficult for most students. This is why supportive elements for auditory learning are necessary – both in frontal teaching and by means of group work.

Mathematics register acquisition

The mathematics register can be seen as "consisting of technical terms, diagrams, and grammatical constructions, such as logical connectives" (Meaney, Trinick, & Fairhall, 2012, p. 199). These elements are learned throughout the entire school process and students are constantly "introduced to further layers of meaning for the terms and expressions they already know" (Meaney et al., 2012, p. 199). Leung (2005) points out that learning vocabulary in mathematics means learning both formal and semantic features of words in various contexts, and involves thinking with and through the

concepts. She calls it an "incremental activity" (ibid.), stating that meanings can develop and expand.

The model for mathematics register acquisition (MRA) was developed to categorize teachers' strategies in teaching the mathematical register and is divided into four stages (Meaney et al., 2012). 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. 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. The control of teachers and support through scaffolding is only necessary in the first two stages; in the final two stages, students gain control. The teacher only needs to provide opportunities to use the new terms. Regarding auditory material, we can see that it 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". In the stage "Intake", it can serve as a language model with which students can work.

Specialized language support through auditory material

As already mentioned, the learning of a language can be supported by training listening competence. Active processing is important for meaningful processing and for memorization of what has been heard. Reasonable and profitable use of auditory material is needed for these processes, e.g., good embedment, listening tasks or segmenting principle. With this in mind, teaching concepts can be developed, in which radio features or other auditory material serves as impulse in the sense of didactical reduction. As acoustic representations are volatilely, there is the need of adding opportunities to document the content of the heard and results of the related tasks within the teaching units. By these means, specialized language support can be ensured. Following these ideas, my research can be focused on the evaluation of auditory educational material in various settings, particularly regarding possible learning effects. The main interest of this research is the use of radio features in mathematics education for specialized language support at the primary level.

Prediger and Krägeloh (2016) refer to a model of three registers relevant for mathematical learning (everyday register, school register and technical register). This model illustrates different levels of verbal representation and how they are connected or built onto each other. Particularly interesting for my research is the question of how children can be led from everyday register to school or even technical register.

School register is an important and necessary factor for successful learning in mathematics. 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, like registering a new language. This applies not only to children with special needs in language development but to every other child. That is the reason why they need linguistic models to develop educational language and to fill terms with representations. These linguistic models are scaffoldings onto which

children can lean (Gibbons, 2002). Lexical storages, which only include words, are not sufficient, as new terms must be used in whole phrases and sentences. According to Götze (2015), language acquisition is, in practice, merely a continuous learning process. There can be setbacks and sometimes children express themselves better in written than in spoken language. This is because everyday register is predominant in spoken language and, oftentimes, deictic expressions are used. This is valid for children as well as for teachers – even if they do so unaware and unintentionally. At this point, auditory educational material could be a useful and profitable addition.

Research questions

The aim of my research is to find out in what way auditory learning material could be of use for language support in mathematics education. For this cause, I want to ask how auditory material, as a language model, can stimulate the development of the school register and how auditory material can support listening competence. In a second step, I want to research what a profitable use of such material could look like.

Methodological approach

Regarding the data collection, I decided to use the design research, based on Wittmann's Design Science (1995). Subject of the Design Science is the construction and research of teaching concepts, including accompanying theories. According to Wittmann (1995), this science is a practice-oriented core area for mathematical education, since it refers to the construction of artificial objects (teaching concepts, curricula etc.) and the research on possible effects in different educational settings.

Based on the Design Science, Prediger et al. (2012) developed the model of design research. The aim of this method is to effectively implement innovations for educational development in teaching practice and empirical research, carried out under realistic conditions. In order to do this, one has to undergo a cycle as pictured in the following illustration.



Figure 1: Model for didactical design research (Prediger & Krägeloh, 2016, p. 95)

The cycle starts at the upper left side of the illustration with the specification and structuring of the learning subject. In my case, this would be the mathematical content of the used auditory material,

which will be specified later in the explanations of the pilot tests. Learning goals have to be developed and the content has to be structured matching those goals. This also means, that important sequences of the feature have to be chosen and cut as the whole feature is far too long (10-12 min) for a profitable use in classroom. Based on this preparatory work, a design is to be developed for the specific learning topic of the used auditory material. In a third step, the developed design is to be performed by means of a design-experiment. In this phase, the concept was tested in teaching practice, data was collected by filming and said data was evaluated. To analyze the student's utterances, the analysis of interaction is used (Krummheuer & Naujok, 1999). Based on the analysis of this data, local theories about the learning subject and the teaching concept can be developed in the last phase. The local theories are the starting point for next rounds of the cycle, in which they can help to optimize the learning goals and concept. Later on, they can be developed to or lead to new local theories itself. Thus, more experiments, data collections and evaluations are to follow, along with new local theories. In this way, after a few cycles, we will not have a perfect teaching concept or representative research results, but rather new and tested theories on the use of auditory media for specialized language support. By now, I finished the first cycle and am currently using my initial experiences to develop local theories, as well as structure the learning goals and teaching concepts anew for the second cycle.

Pilot testing

For the pilot testing, I designed a teaching unit in the form of a project day in a fourth-grade classroom with four 45-minute classes. The class is made up of 16 children, all of whom participated in this project day. A teacher, who was specially trained for this project, instructed the unit. The topic of the unit was "Probability and Random Experiments", as it was developed based on the radio feature "Wann ist ein Spiel fair?" (When is a game fair?) from the Kinderfunkkolleg Mathematik (https://www.kinderfunkkolleg-mathematik.de/themen/wann-ist-ein-spiel-fair). In this feature, four students are planning to play a game in order to make a decision. They realize the need to test the fairness of the game, start an experiment to do so and find out that the game is unfair, since they don't have equal chances. While testing the game and talking about the mathematical problem, they use school register and mathematical terms. Thus, the students in the class that was observed and filmed were confronted with new terms in a playful way. The overall aim of the unit was the conceptual development of "fairness" (through language) while the linguistic aim was the understanding of the following terms which were presented in the radio feature: double, street (as the subject of the feature was a dice game with the winning options "double" and "street"), probable, option, coincidence, fair, unfair, unsafe, unlikely, likely and safe. Those aims work together: language development can help to develop the concept. Throughout the entire day, both the class situation as well as the working phases in smaller groups were filmed. This way, enough data was gathered referring to the individual processes of the children's speech development, while at the same time it was possible to research on what a profitable use of this material could look like. For the second testing, these experiences can be used to improve the unit and the use of auditory material.

The first lesson began by listening to the first part of the radio feature in which two children were arguing about the fairness of a dice game. In class conversation, the students repeated the content of

the heard, reviewed the game and tested the fairness of that game in various steps that built on one another. In between those steps, more parts of the radio feature were presented, and a lexical memory was collectively developed based on the content of these features. In the second part of the day, the students verified the chances of winning and determined the fairness of various other games during learning stations. Hereby, they had to transfer their acquired knowledge whilst using the structures of language and reasoning they had been offered and trained through the radio feature. In Figure 2, you see two exemplary stations referring to game fairness. Other stations were about dicing with different winning numbers and about dicing with six- or ten-sided dice, about throwing different amounts of reversible tiles and about picking different colored balls from an urn.



Figure 2: Exemplary stations of the learning stations

In groups of two, students chose a game for which they would be experts. Each group had to test every game, but they only had to work on a worksheet for their expert station. On that worksheet they had to describe and to reason whether or not that specific game was fair or unfair. If the game was unfair (which all of them were), they also had to explain why the game is unfair and how one could make this game fair i.e. how to increase the chances of winning for the losing card, colour etc. so that the chances become equal. After the learning stations, students ended the unit with the presentation of their "expert stations". Each group presented their station, outlined how they examined the game and shared their results. They also presented a solution on how to make the game fair.

Initial experiences

Initial observations showed that students were highly concentrated while listening to the radio features. Due to the fact that students know audio-plays from their everyday life and free time, this proved to be highly motivational and made the mathematical content more exciting. The feature and its "story" involving mathematical content served as an effective conversation starter for the students' discussion. It can already be reported that the method is currently being adjusted for the second cycle of the design research by designing the testing more as a laboratory situation and less of a whole teaching experiment. In that way, it is possible to research more about the individual

processes of the speech development of the children. Still, it can already be stated that nearly every student was able to correctly repeat what he or she had heard. If anything was unclear, it was easy to repeat a certain part of the radio feature individually or in front of the whole class. In this way, auditory material can counteract transitory learning through possible repetition. Through the combination of listening, repetition (if needed) and conversation, the use of radio features successfully aided the development of lexical memory and was helpful when introducing new terms. In the beginning of the unit, the students were only able to explain abstract terms such as "fair" with help of examples:

Teacher: So what actually is fair?

Student 1: Uhm fair is.. mh.. when you say for example if t w o uhm for example o n e gets a gummi bear and the other one not then they find this unfair and fair is if the other one also gets a gummi bear.

This explanation could be considered a form of everyday register, as the speaker describes an everyday example using everyday register. However, this changed throughout the four hours of the project. During the final presentation of their investigated games, the students were allowed to look at their worksheet and their written answers for support. Interestingly, they did in fact use the new mathematical terms and phrases while arguing about the game's fairness.

- Student 1: Uhm it's unfair because uhm the game is unfair because there are eight of blue, one of red, red of two uhm.. red two of them.
- Student 2: No there's only one of red.
- Student 1: Yes. Two of green and four of orange. Because you have more chances with blue and the others have less.. (reads the next question) *If the game is unfair, what would you have to do to make it fair?* You'd have to change the game so that everybody had equal amounts of uhm cards of every colour then everyone would have equal chances and the game would be un uhm fair.

Teacher: Very good, thank you.

Here we see that the speaker uses school as well as technical register. Mathematical terms and phrases, such as, "It's unfair because...", "more chances", "equal amounts of..." and "equal chances" – that appeared in the radio feature when the protagonists were examining their dice game – are not only used by the students, but also used correctly. Referring to the MRA model explained above, there has been a development from the stage "Noticing" – where new terms or expressions are introduced – to the second stage "Intake" – which describes the process of understanding. There are also first elements of the third stage "Integration", as there is testing, feedback and modification in the investigation of the game's fairness. To reach the last stage "Output", the children would need to be able to use the new terms fluently without support. In this case, the children still have the support of their written answers on their worksheets while presenting their results, so we are unable to tell for sure if they reached this stage. However, it is clear that there is a development from stage one to three – from noticing to integration. This indicates that there is an apparent improvement in the students' mathematical expression throughout the teaching unit. Children are offered

professional language and are thus challenged to intake and use it. The absence of visuals, gestures and deictics in auditory material (unlike YouTube videos etc.) is a big challenge and opportunity for language development which worked out in my pilot testing quite well. Thus, as a first conclusion, it can be stated that radio features or auditory material in general can indeed serve as verbal language support in mathematics education. The goal of my main study is to verify and specify this statement for other mathematical topics, to further research on the use of the features in laboratory situations and to develop various possible applications of radio resources as auditory learning material.

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