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# A qualitative analysis of the use of Book Creator functions while processing Fermi questions

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*In a qualitative empirical study, it was investigated how primary school children solve Fermi questions using the app Book Creator. The research project aims to investigate how the app with its functions is integrated into the elaboration process and which negotiation processes can be reconstructed within the group work processes. This article will focus on the app functions. In a first evaluation step, it will be shown which functions the students used and to what extent. With the help of qualitative content analysis and inductive development of a category system, it will be worked out which content-related functions these technical functions of the app fulfil in the elaboration process.*

*Keywords: Digital books, primary schools, qualitative content analysis, qualitative research.*

## Introduction

Learning with digital media has become increasingly important in mathematics education in recent years. Studies have been able to show a positive influence of digital media on mathematics learning (Hillmayr et al., 2020). However, it is important to note that the presence of technology alone does not improve learning. The decisive factor here is the pedagogical content knowledge of teachers (Drijvers et al., 2016). Within German-language mathematics didactics research, it is emphasised that the use of digital media must always be justified first and foremost on the basis of didactic considerations (Krauthausen, 2012). It is reasonable to focus on media-specific potentials instead of discussing the added value of digital media. The combination of analogue and digital tools in the sense of a duo of artefact is considered useful (Ladel, 2018).

The research project on which this article is based focuses on students working on Fermi questions with the help of the app *Book Creator*. Fermi questions, often referred to as Fermi problems, are open-ended questions that contain little or no data to solve the problem. This data must be researched, determined, estimated or obtained through everyday knowledge in the processing process. It is not about right or wrong answers but about making reasonable and plausible assumptions (Peter-Koop, 2005). The project wants to investigate how the app is integrated into the solution process and which social and content-related negotiations can be reconstructed within the group during the process.

In this article, the following research question will first be investigated in a first evaluation step: Which functions of the Book Creator are used while processing Fermi questions and which content-related functions do they fulfil within the elaboration process? For this purpose, the app and its' most important functions will be presented primarily. Following, the research design is examined in more detail and the results of the evaluation are presented. An outlook on the further research procedure will be given concludingly.

## **App Book Creator**

The *Book Creator* app is a digital tool that allows users to create and design multimedia books by integrating different media such as text, images, audio and video files. Saved photos and videos can be inserted via the photos function. In addition, photos and videos can be taken and inserted directly in the app through the camera function. The pen function offers the possibility to create freehand drawings or handwritten texts through gesture control or with help of the Apple Pencil. Using the text function, texts can be written via a virtual keyboard. The sound function can be used to insert sound recordings stored on the tablet. It is also possible to create and insert voice recordings directly in the app. The intuitive operation and the simply designed user interface make the app suitable for use in primary schools (Bierbrauer, 2018). In contrast to frequently used didactically rather questionable apps, which aim at practicing superficial procedural knowledge (Klinger & Walter, 2022), the Book Creator offers the possibility to design comprehension-oriented learning.

According to Schäfer and Brandt (2022), three different types of e-books can be distinguished in the classroom: consuming, producing and combining. The consuming e-book is created entirely by the teacher and then made available to the learners for processing. Producing e-books, on the other hand, are designed exclusively by the learners. The starting point is a new, empty book, which is filled with the learners' own content during the elaboration process. A combining book contains both: consuming (created by teacher) and producing (created by students) elements. At the beginning of the elaboration process, an e-book created by the teacher is available to the learners. In the further process, the students actively influence the design of the book by adding and editing content (Schäfer & Brandt, 2022). For the research project presented in this article, combining e-books were used in the empirical study. More details of the research design are presented below.

## **Research design**

For the empirical study, a learning environment was developed in which the children work independently on a Fermi question in groups of three students each. This learning environment was tested in a pilot study in December 2021. The main study took place in summer 2022. The learning environment was implemented in five different classes (four times grade four, once grade three). These were classes of three different urban public primary schools. Classes A, B, C can be described as a more affluent demographic with a low proportion of German as a second language (L2). Classes D and E can be described as low-income. Class D has a high L2 share; class E has a medium L2 share. Now following, an insight into the conception as well as data collection and evaluation methods will be presented.

### **Conception of the learning environment**

Since the children had no previous experience with tablets and were not familiar with the Book Creator app, an instructional design was conducted in advance of the learning environment for the Fermi questions, which served to familiarise and try out the Book Creator with its various functions. Following the pilot, the concept was concretised and adapted regarding the use of the sound function. The revised learning environment was finally structured as follows: At the beginning, the children were presented with an e-book created with the Book Creator, which provided information about Fermi questions. With the help of this book, a specific question was worked on cooperatively. This

introduction was important because the classes had no previous experience in working on Fermi questions. The children were given the task of solving a problem themselves and capturing their process with the help of the various Book Creator functions. They were to document their solution process in a way that was comprehensible to others. Explicit reference was made to the use of the sound function in order to be able to additionally describe and explain the procedure. This was followed by the processing phase, in which the groups could choose one of the following three tasks to work on: How much do all the children in your school weigh together? How many rolls of toilet paper does a child use in a year? How big would a man be who had such a big head?<sup>1</sup>

As already mentioned, combining books were used in this research project. In concrete terms, this means that for each Fermi question, an e-book prepared by the researcher was available to provide orientation and assistance. In addition to the respective question, hints for working on Fermi questions could be found on the first pages. To structure the process, the children were first asked to formulate auxiliary questions for the given question in order to divide the problem into sub-problems. The pupils were given blank pages in the book to work on these auxiliary questions. In order to offer further assistance, exemplary auxiliary questions were found at the end of the book. These could structure the children's solution process if necessary, but at the same time also provided a concrete solution strategy.

### **Data collection method**

The group work phase was accompanied by videography. Four to six groups were filmed with one camera each.<sup>2</sup> In addition, the screen recording function of the iPads was used to be able to include the actions with the app in the evaluation. The video material and the e-books created thus form the basis for the subsequent data analysis.

### **Evaluation method**

For the evaluation of the data, a combination of qualitative content analysis (Mayring, 2014) and methods of interpretative classroom research (Brandt & Tatsis, 2009) were chosen. The qualitative content analysis will first provide an overview of the data material in order to identify initial categories here that form an inductive basis for a more in-depth analysis based on interpretative classroom research. In this next step, the group processes during the processing of Fermi questions will be analysed. The video material will first be viewed and scenes will be selected for transcription on the basis of the results of the content analysis. The selected scenes will be evaluated with the help of interaction analysis (Brandt & Tatsis, 2009), which is methodologically based on the theoretical foundations of symbolic interactionism and ethnomethodology .

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<sup>1</sup> This question was accompanied by a photo of a 13-metre-high sculpture depicting a person's head on a pedestal. A person could be seen directly in front of the sculpture.

<sup>2</sup> The decision as to which groups were filmed was based on the parents' respective declarations of consent to conduct the video study.

This article focuses on the first evaluation step and thus on the analysis of the e-books with the help of qualitative content analysis. First, the functions used are recorded in a counting-quantitative way. This quantitative recording of qualitative data does not serve the purpose of completely quantifying the data, but rather represents an initial orientation in order to make tendencies and patterns in the use of the functions visible. In addition, in order to make visible which contents are thereby represented in the elaboration process, the individual contributions are classified into a category system. The categories are formed inductively from the material. The results of the individual evaluation steps are presented below.

## Results

### Use of the functions

With regard to the entire sample, it was found that the text function was used by far the most (65%). The pen function and the sound function were used in roughly equal proportions. The camera function was only used in very rare cases (Table 1).

**Table 1: Use of the functions**

Class	Text		Pen		Camera		Sound		Total	
	Count	Percentage	Count	Percentage	Count	Percentage	Count	Percentage	Count	Percentage
A	39	74%	4	8%	0	0%	10	19%	53	100%
B	30	73%	4	10%	0	0%	7	17%	41	100%
C	57	83%	4	6%	5	7%	3	4%	69	100%
D	25	46%	15	28%	0	0%	14	26%	54	100%
E	31	48%	22	34%	0	0%	11	17%	64	100%
Total	182	65%	49	17%	5	2%	45	16%	281	100%

Looking at the individual classes more closely, it becomes clear that in each class the text function was used most frequently. In two classes (A and B), the sound function was used much more frequently than the pen function. In two classes (C and D), both functions were used to about the same extent. In class E, the pen function was used significantly more often than the sound function. Except in class C, the camera function was hardly used or not used at all. From the researcher's point of view, the resulting photos fulfil exclusively decorative functions and are therefore not considered further in the following explanations. After this quantitative overview, the following section will describe the content-related function of the Book Creator functions used.

### Content-related function of the Book Creator functions

In order to answer the question of which content-related functions the app functions fulfil, categories for these content-related functions are first developed. Then the relationship between the developed categories and the app functions is presented. The recording unit (Mayring, 2014), which is the basis for the development of a category system, includes the children's e-books that were created. A

contribution is always coded that was created by using one of the described Book Creator functions, for example, the content of a text field or the content of a sound recording. Coding unit (minimum material component that can fall under a category (Mayring, 2014)) and context unit (maximum material component that can fall under a category (Mayring, 2014)) thus coincide in this evaluation and are subsequently referred to as contributions. The categories inductively developed from the e-books are presented in Table 2 with anchor examples and are briefly explained below.

**Table 2: Category system**

Category	Anchor examples
1: Auxiliary questions	“Wie viel wiegt ein Kind?” “ <i>How much does a child weigh?</i> ” (E4); “Wie viel Toilettenpapier verbraucht ein Kind am Tag?” “ <i>How much toilet paper does a child use per day?</i> ” (D2)
2: Calculation	“ $35 \cdot 300 = 11500$ ” (A3); “Sechzig mal vier das sind zweihundvierzig Kinder” “ <i>Sixty times four that is two hundred and forty children</i> ”(C1)
3.1: Answer value	“365” (D2), “25kg” (A3)
3.2: Answer bullet points	“Am Tag 10 Stück” “ <i>10 pieces a day</i> ” (C3); “Insgesamt Größe 17 m” “ <i>total size 17 m</i> ” (B5)
3.3: Answer sentence	“Eine Klasse wiegt 625 kg” “ <i>One class weighs 625 kg</i> ” (B4); “365 Tage hat ein Jahr” “ <i>A year has 365 days</i> ” (E1)
4: Heading	“Infos” “ <i>Info</i> ” (A1); “Rechnung” “ <i>Calculation</i> ” (C5)
5: Process description	“Hier beantworten wir die Fragen” “ <i>Here we answer the questions</i> ” (D1); “Wir haben im Kopf gerechnet” “ <i>We have calculated mental</i> ” (A3)
6: Reason	“Die 4. Klassen haben ungefähr 75 Kinder, denn wir haben $3 \cdot 25$ gerechnet” “ <i>The 4th grade have about 75 children, as we have calculated <math>3 \cdot 25</math></i> ” (B3); “In jeder Klassenstufe gibt es 60 Kinder. Es gibt 4 Klassenstufen. Deswegen 60 mal vier” “ <i>There are 60 children in each grade. There are 4 grade. Therefore 60 times four</i> ” (C1)

*Auxiliary questions* are questions formulated by the children for intermediate results that are intended to help answer the Fermi question. Contributions that involve the operative linking of at least two numbers are counted as part of the *calculation* category. The naming of a result is not necessarily required. The *answer* category includes the answers to the auxiliary questions or the Fermi questions and was differentiated into three subcategories. The contributions that consist exclusively of the naming of the numerical value and optionally the corresponding unit were assigned to the *answer value*. The contributions that contain further information in addition to naming the corresponding value, but syntactically do not represent a sentence, were coded as *answer bullet points*. All other answers syntactically represent a sentence and were assigned to the subcategory *answer sentence*

accordingly. The category *heading* includes those contributions that serve to structure the book and give the potential reader information about the following contributions. *Process descriptions* are those contributions that provide information on how a procedure was or is carried out or through which actions a result was achieved. Finally, the category *reason* includes the contributions that contain reasons for the determination of a value. It should be noted that a contribution can be assigned to several categories. For example, the text contribution of group D2 "How much toilet paper does a child use per day? Estimated: 30" is assigned to the categories auxiliary question ("How much toilet paper does a child use a day?"), process description ("estimated") and the subcategory answer value ("30").

The results of the coding are summarised in Table 3. For reasons of space, the entire sample was presented here and no subdivision into the individual classes was made.

The text function was most frequently used to write down answers (53%). These contributions were mainly written as a value or sentence (23% each). A small proportion of the answers were written as bullet points (7%). Furthermore, the text function was often used to write down auxiliary questions (32%). It was used less frequently for headings (9%) and calculations (8%) and hardly at all for reasons and process descriptions (2% each).

**Table 3: Coding of the functions**

Category		Text		Pen		Sound		Total	
1: Auxiliary question		59	32%	3	6%	8	18%	70	25%
2: Calculation		15	8%	12	24%	12	27%	39	14%
3: Answer		96	53%	35	71%	17	38%	148	53%
	3.1: Answer value	41	23%	32	65%	0	0%	73	26%
	3.2: Answer bullet points	13	7%	0	0%	1	2%	14	5%
	3.3: Answer sentence	42	23%	3	6%	16	36%	61	22%
4: Heading		16	9%	2	4%	2	4%	20	7%
5: Process description		3	2%	0	0%	28	62%	31	11%
6: Reason		4	2%	0	0%	6	13%	10	4%

The pen function was mainly used to record answers (71%). These were largely written down as an answer value (65%), hardly ever as a sentence (6%) and not at all as a bullet point. It was also used more often to document calculations (24%). It was used less often for auxiliary questions (6%) and headings (4%). The pen function was not used to capture process descriptions or reasons.

In contrast to the other two functions, the sound function was mainly used for process descriptions (62%). It was also frequently used to answer questions (38%), almost exclusively in the form of a sentence (36%). The function was also used to give calculations (27%) and auxiliary questions (18%) and to give reasons (13%).

When looking at the functions as a whole, they were most often used to record answers (53%). These were realised in the form of values (26%), sentences (22%) and bullet points (5%). They were also used to record auxiliary questions (25%), calculations (14%) and process descriptions (11%). Overall, they were little used for headings (7%) and reasons (4%).

## **Summary**

The fact that the functions were most often used to record answers and thus much more often than for documenting auxiliary questions seems unsurprising, since the groups answered their own auxiliary questions as well as already given auxiliary questions that were available as help at the end of the book. When looking at the different use of the functions it is noticeable that descriptions and reasons were mainly realised through the sound function, i.e. through the orally spoken word. When using the text function or the pen function, on the other hand, descriptions and reasons played hardly any role or none at all. With regard to the form of the answers, it is also noticeable that the most elaborate linguistic form, namely the answer sentence, is used in the oral (sound function). In contrast, in the handwritten form (pencil function), linguistically less elaborated forms (value and bullet point) are mainly used. In the keyboard-written form, the linguistically simplest (answer value) and most complex form (answer sentence) are used in equal measure. With regard to the data, it therefore seems that the conceptually written (Koch & Oesterreicher, 1994) plays a greater role in medially oral forms than in medially written forms.

## **Outlook**

In relation to the overall project, the results indicate that the app is an integral part of the solution process and fulfils various content-related functions. The results form the starting point for analysing the group processes in terms of which negotiations lead to the decision for a certain type of documentation (e.g. answer sentence in the form of sound recording). The transcripts of the videotaped group processes will serve as the empirical basis for this. By the means of interpretative classroom research such as interaction analysis (Brandt & Tatsis, 2009), it will be investigated how the individual groups arrive at the formulated contributions in the joint negotiation process and what role the concepts of orality and writtenness play in this. Abductive inferences (Krummheuer & Brandt, 2001) are used to explain phenomena occurring in the group process by generating hypotheses. By comparing different analyses with each other and with the results presented here, well-founded statements should finally be made and thus a contribution made to theory development within mathematics didactics.

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