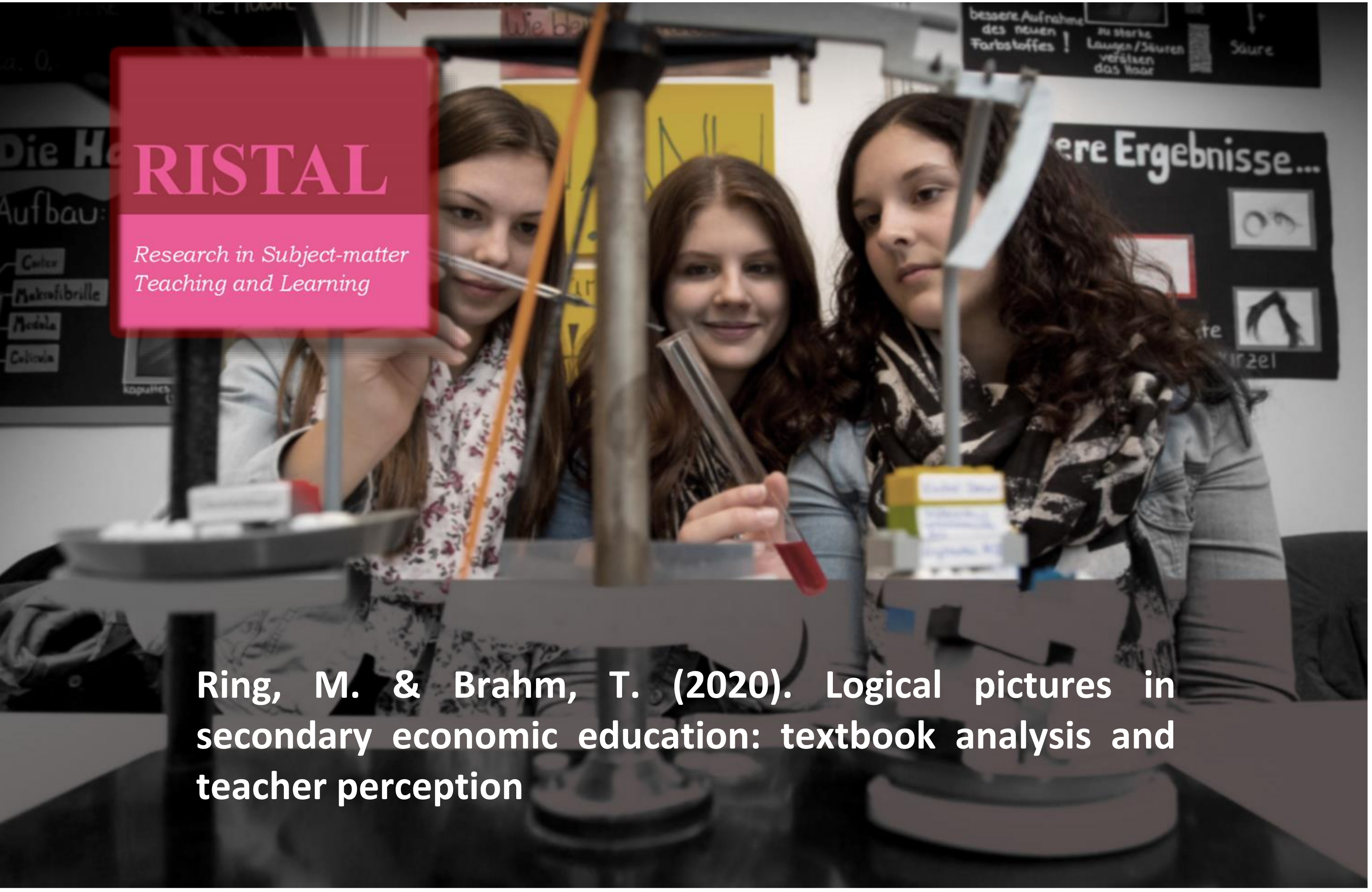

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Logical pictures in secondary economic education: textbook analysis and teacher perception

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Abstract

Logical pictures, such as graphs and charts are an important part of instruction, not only in economic education. Learning with these logical pictures might be beneficial under appropriate conditions, however, domain-specific and visualization-specific challenges might impede learning. In this paper, we study the use of logical pictures in secondary economic education learning material and in economics teaching. In a mixed-method approach, we first analyze 450 logical pictures and propose a category system which distinguishes between the form of a logical picture as well as its domain-specificity. In a second step, we conducted teacher interviews with economic teachers. Results show that logical pictures are used frequently in textbooks, with graphs occurring more often than charts. The interview findings support the relevance of graphs and charts for instruction and provide information about the necessary student abilities and their challenges when working with different logical pictures in economic education from the teacher's perspective.

Keywords:

visual representations; logical pictures; graphs; charts; diagrams; secondary economic education, Germany

1 Introduction

In social sciences, logical pictures such as graphs and charts are used to visualize and communicate about data, ideas and systems. Accordingly, they are a ubiquitous part of instruction and experts regard visualizations as an important explanation tool for economics (Schopf, Raso, & Kahr, 2019). In higher education, some authors even argue that graphs are more important than algebra or calculus for teaching and learning economics (Hey, 2005).

For the use of logical pictures in learning settings, the question *which* logical pictures are used and *how* they are used is highly relevant for multiple reasons. First, different formats of representations can influence mental model building (Schnotz & Kürschner, 2008) and thus affect how students understand economic concepts such as price building (Jägerskog, 2020). Furthermore, different formats come with their own set of necessary abilities and learner challenges, for example missing graphical literacy for graphs and maps (Åberg-Bengtsson & Ottosson, 2006) or difficulties with statistical concepts for histograms (Boels, Bakker, van Dooren, & Drijvers, 2019). When comparing between domains, different logical pictures are used, (e.g. maps in geography, equilibrium graphs in economics) and even the same logical picture might be use dif-

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ferently, as different information is relevant for the domain question (Cook, 2011). To sum up: the use in classrooms, the tasks as well as the challenges of logical pictures for learners are highly specific for a certain domain (Ainsworth, 2006) and for the respective representations (Schnotz & Kürschner, 2008).

For economic education, most research discusses the use of graphs and charts in higher education (e.g. Cohn, Cohn, Balch, & Bradley, 2001; M. Davies, 2011), but little research has been conducted at secondary level (e.g. Aprea & Bayer, 2010; Jägerskog, 2020).

Although the understanding of logical pictures depends on their form and their use in teaching, few studies have focused on what kind of logical pictures are used in learning material or how economic teachers use logical pictures in their teaching. Thus, the objective of this study is to investigate the use of logical pictures in secondary economic education in an exploratory approach.

2 Literature review

2.1 Logical pictures as graphical representations

Graphical representations in general are illustrations that are used in learning material and, thus, encompass pictures, drawings or caricatures as well as graphs, charts or diagrams. There are different taxonomies of graphical representations in learning material that differ in their scope (i.e. what kind of representations they focus on), their terminology (what different representations are called) and their criteria for classification (form vs. function). Although there are some similarities, no classification is universally accepted yet (Ainsworth, 2006).

Regarding *scope*, some classifications are focused only on specific types of representations (and, thus, differentiate, for example, between graphs, charts and diagrams, see Winn, 1987); others classify different representations on a higher level and therefore distinguish between text, realistic pictures and logical pictures (e.g., Schnotz, 2001). Furthermore, the various classifications use different *terminology*, a “chart” in one classification, might be a “graph”, a “diagram”, an “infographic” or a “visual representation” in another framework (e.g. Harris, 2000; Kosslyn, 1999). From a literacy perspective, researchers also use the term discontinuous text, for example, when describing the use of visualizations in geography (e.g. Huber & Stallhofer, 2010). Lastly, most scholars use structural-form characteristics to categorize (e.g. Winn, 1987) whereas others use the relationship between the representation and the represented object (e.g. Schnotz, 2001) or distinguish pictorial elements in learning material according to the function they serve when they are combined with text (e.g. Levin, Anglin, & Carney, 1987).

In this paper, we use the classification of Schnotz (2001) to categorize different visual representations based on the similarity of the represented object and the representation and to clarify our focus on logical pictures in economic education (see Figure 1).

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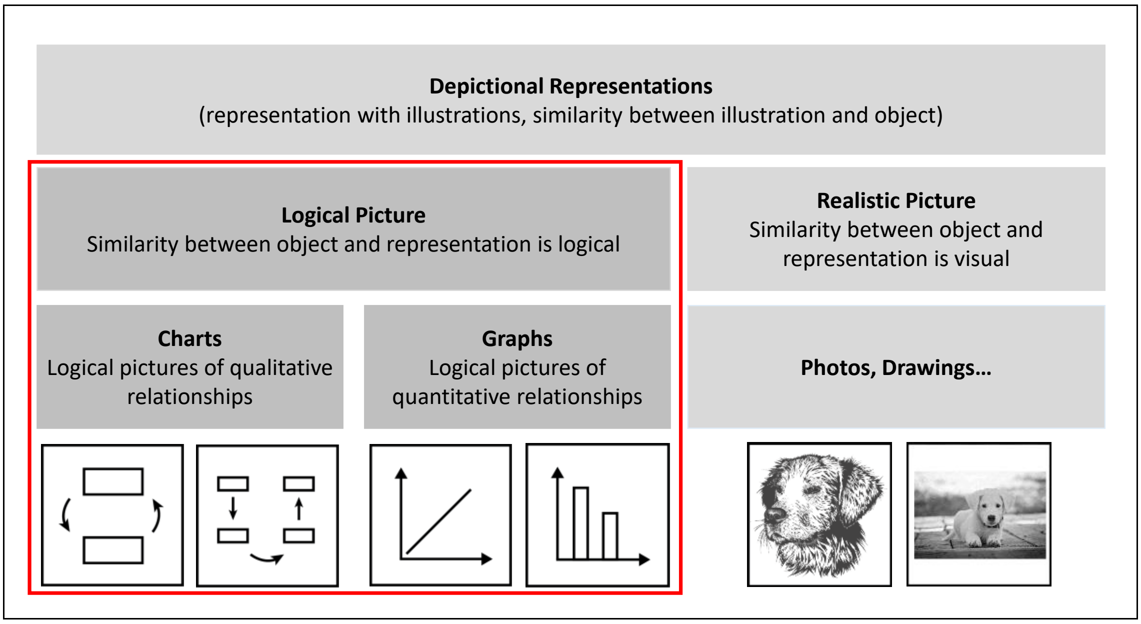

Fig. 1: Classification of depictional representations based on Schnotz, 2001

A "depictional representation" describes a real object with a visual-graphic representation. Schnotz (2001) further distinguishes between pictures, where the relation between the object and the representation is visible (e.g. a photograph) and charts and graphs (=logical pictures), where the relation between the object and the representation is logical (Schnotz, 2001). Based on this terminology, we use the term "logical pictures" to refer to representations where the relationship between the represented object and the representation is logical. Within the category of logical pictures, the term "charts" is used to describe visualizations of relationships between distinct objects (hierarchy, process flow, structure…). In charts, the relationships are often displayed with lines and arrows, which are interpreted differently depending on the context (e.g. as "part-of", "consequence of", "before-after" etc.). In comparison, we refer to "graphs" as logical pictures of quantitative relationships (bar graphs, line graphs…). For graphs, spatial distances can be meaningfully interpreted as differences between represented objects or relationships (e.g. if one slice of a pie graph is bigger than another, the number it represents is also bigger by the same percentage); as a result, they normally have clear reading rules, i.e. compared to charts, where the meaning of an arrow can change between charts, the height of a bar in a bar graph can be interpreted in the same way in different bar graphs.

2.2 Representational competence and domain knowledge

In science education, rather specific terms like graph comprehension (Lai et al., 2016; Peterman, Cranston, Pryor, & Kermish-Allen, 2015; Shah, Freedman, & Vekiri, 2005) or graph literacy/graphicacy (Åberg-Bengtsson & Ottosson, 2006; Galesic & Garcia-Retamero, 2011; Ring, Brahm, & Randler, 2019; Roberts et al., 2013) are used to describe the ability to work with certain kinds of representations. In contrast, the broader set of knowledge and skills to make sense of different representations is referred to as representational competence (Gebre & Polman, 2016; Kozma & Russell, 1997; Nitz, Ainsworth, Nerdel, & Prechtl, 2014; Stieff, Scopelitis, Lira, & Desutter, 2016). The ability to deal with typical representations and to fluently use them to communicate about domain principles is seen as the mark of an expert in a domain (Kozma, 2003; Kozma & Russell, 2005). In economic education, for example, graphs are used to discuss the relationship between price, supply and demand. The ability to work with these graphs is an important part of expertise and learners who fail to understand these graphs reveal "that they have not developed an economist's way of thinking and practising" (P. Davies & Mangan, 2007, p. 721). In this regard, one of the ongoing debates in this research field is the relationship between the content or domain of a representation and the representational competence (Ainsworth, 2006). The author argues that in order to learn properly with representations within a domain, learners need to understand the form of representation, the relationship between the representation and the domain, as well as the rules how to select and construct an appropriate representation within the domain. Another debate refers to the importance of prior knowledge: Different studies identified the so-called *representational dilemma* (Dreher & Kuntze, 2015; Rau, Aleven, & Rummel, 2017): teachers have to enable learning *about* representations (e.g. how to read a certain graph) and learning *from* representations (e.g. what does the graph tell us for the domain question).

2.3 Challenges when learning with logical pictures

In graph research, scholars address students' strategies to work with logical pictures as well as their common mistakes, errors or misconceptions (Glazer, 2011). For instance, Åberg-Bengtsson and Ottosson (2006) show that tasks that go beyond the most obvious relationships and the reading of simple data points may be difficult for older students and even for college students when reading science graphs. Similarly, the connection between science concepts and graphical representations is a major challenge for students at the secondary level (Lai et al., 2016). Moreover, young adults are challenged when constructing a graph from data and given text and struggle with labelling axes or choosing the right graph type (Kotzebue, Gerstl, & Nerdel, 2015). Additional challenges regarding graph comprehension include confusing an interval and a point, difficulties with graph interpretation which result from design/format choices (e.g. features such as color, size, scale…) and (preservice-)teachers lacking expertise (Glazer, 2011). For histograms, Boels et al. (2019) summarized conceptual misconceptions possibly resulting from misunderstanding central statistical concepts - data (e.g., number of variables and measurement level) and distribution (shape, center and variability or spread). In addition to challenges with specific logical pictures, one of the major challenges is connecting and using multiple representations (text, equations, logical pictures) to answer domain questions (Kozma, 2003).

Most of these problems, however, are reported in the context of STEM-education and primarily for line graphs or histograms. We might expect some of these problems to be representation-specific and thus, potentially valid across different domains. Nevertheless, it remains unclear if these are "typical problems" for representation-related tasks which are also relevant for the economic domain and whether there are additional problems in the context of social sciences (as suggested by Westelinck, Valcke, Craene, & Kirschner, 2005).

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2.4 Research aims

Since research on representational competence in economic education is scarce, we apply an exploratory approach and focus on which logical representations are used to what extent and how they are used in authentic classroom settings. Our aim is to shed light both on the most relevant representations and on the relevant abilities and typical challenges that arise in the context of economic education as a social science in secondary education. For this purpose, we conducted two studies: First, we analyzed logical pictures, i.e. the graphs and charts in the available economic textbooks in south-west Germany. As a result, we developed a category system that not only differs between the form of a representation (graph vs. chart) but also distinguishes between different levels of domain-specificity. With that in mind, in a second step, we aim to include the teaching perspective in the study by interviewing economic teachers how these different logical pictures are used in authentic economic classroom settings and what domain-specific and representation-specific challenges and competences students show when working with these representations.

3 Study 1: Textbook analysis

3.1 Methods

3.1.1 Selection of textbooks

In order to identify and analyze relevant logical pictures, we used textbooks for the new school subject "economics, vocational and study orientation" [Wirtschaft, Berufs- und Studienorientierung] (grade level 8-10) in Baden-Württemberg/Germany for higher secondary school ("Gymnasium"). School books were chosen since they can be seen as a close representation of the potentially implemented curriculum (Valverde, Bianchi, Wolfe, Schmidt, & Houang, 2002) and are used as indicators of teaching practice in (social) science education (e.g. Strippel, Tomalla, & Sommer, 2018; Zimenkova, 2008). The analyzed corpus consists of all four available school books which were written in accordance with the official curriculum for the subject (Altmann, Boss, & Göser, 2018; Biehahn, Jüngling, Machoczek, Michael, & Ottmar, 2018; Burghardt et al., 2018; Kochendörfer, 2018) as well as the only textbook available (to our knowledge) for the upper secondary level (Bauer, Hamm-Reinöhl, Podes, & Riedel, 2012). Since the subject was newly introduced for grade levels 8-10 in the curriculum reform of 2016, it has only been taught in schools since the school year 2018/2019. Since these school books are the only ones available, they provide good insights into the amount and content of visualizations used for the subject economics. In total, we analyzed all 450 logical pictures available in the five school books in order to gain a comprehensive overview of the visualizations used.

3.1.2 Procedure

Due to the focus on logical pictures, in a first step, we excluded every visualization that was either an image, a drawing, a comic or a text-representation which showed minimal design elements (e.g. pro-contra lists) from the classification. Second, based on

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the two different groups of logical pictures described in section 2, a representation with a logical connection between object and representation, was labelled as chart if it represented qualitative relationships (e.g. flowcharts, hierarchical charts etc.). In contrast, a representation of a quantitative relationship was labelled as graph (e.g. line graphs, bar graphs, equilibrium graphs…). In a third step, we distinguished according to the domain-specificity of the logical pictures and distinguished between descriptive logical pictures which use every day terminology, logical pictures with domain terms and lastly typical visualizations of domain principles. With this category, we connect research focusing primarily on graph reading of rather descriptive – quantitative – representations (e.g. Åberg-Bengtsson & Ottosson, 2006), and studies that analyze the interplay between domain knowledge and visual representations (e.g. Lai et al., 2016). The latter stream of research works with visualizations of domain principles (e.g. Prey-Predator Relationship in biology).

All 450 visualizations of the school books were then rated by two independent raters based on these categories (see Table 1 and anchor examples). The interrater reliability was *Cohens Kappa* of 0.93 for the category "form" and 0.58 for "domain-specificity". To achieve a clear count for further analysis, cases of dispute were solved by a third rater.

Tab.1: Category system for textbook analysis

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="3">Domain specificity</td></tr>
<tr><td>None</td><td>Low-middle</td><td>High</td></tr>
<tr><td rowspan="2">Connection between object and logical picture</td><td>Quantitative relationship
"Graph"</td><td>Descriptive graph</td><td>Graph with domain terms</td><td>Graph with domain principle</td></tr>
<tr><td>Qualitative relationship
"Chart"</td><td>Descriptive Chart</td><td>Chart with domain terms</td><td>Chart with domain principle</td></tr>
</table>

3.2 Results

3.2.1 Anchor Examples

Based on the category system, table 2 shows the anchor examples of the different categories in German. In the following, the examples will be briefly described to illustrate the different categories that we found in the school books.

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Tab.2: ***Category system for textbook analysis*** *(sources of anchor examples in appendix, publication with permission by the right holders)*

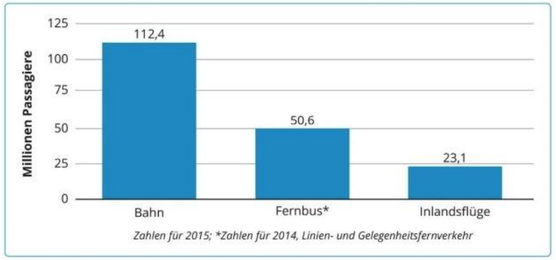
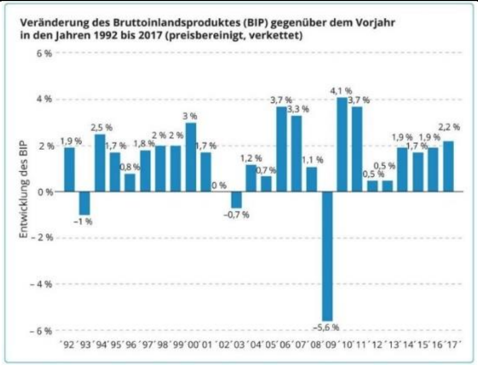
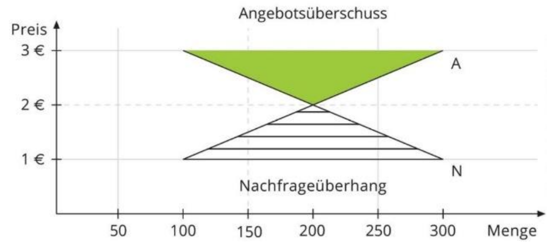
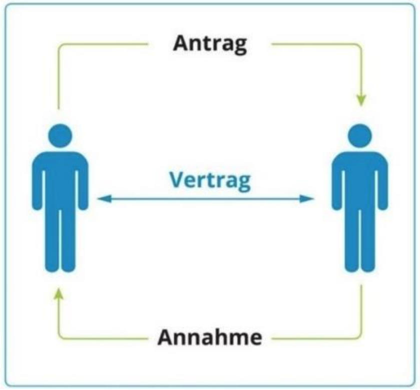
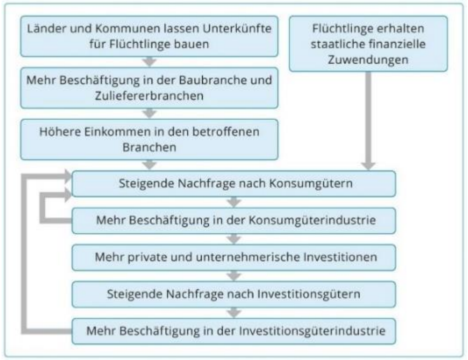
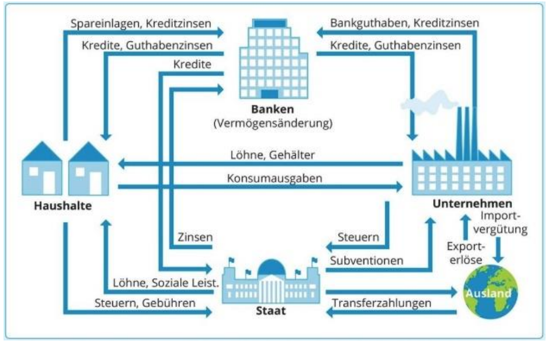
		Domain Specificity		
		No domain specificity	Low-middle domain specificity (terms)	Highly domain specific (principles)
Form	„Graph“			
	„Chart“			

Fig. 2-7: Anchor examples presented in table 2 (no individual captions)

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Descriptive graphs without domain-specific terms do not require any domain knowledge. The anchor example (upper left panel in Table 2) visualizes the number of passengers in millions that use railway, long-distance buses or domestic flights as means of transportation. These graphs require knowledge of graph reading rules.

The anchor example for **graphs with domain-specific terms** (upper middle panel in Table 2) is a bar graph that depicts the change in the gross domestic product compared with the previous year between 1992 and 2016. In addition to graph rules, economic knowledge of the term gross domestic product is necessary. Furthermore, context knowledge might be necessary to interpret some parts of the graph, e.g. the drop of GDP in 2009 as a result of the global financial crisis.

The anchor example for **graphs visualizing domain-specific principles** (upper right panel in Table 3) shows the excess supply/demand in Marshall's supply and demand graph. Knowledge of the underlying terms (e.g. excess demand) and of the principles (price develops from an equilibrium of aggregated supply and demand) is necessary to work with this model. With respect to the graph reading rules, this graph additionally differs from graphs in other disciplines. While the independent variable is regularly represented by the x-axis (in math and STEM disciplines), in this graph, the independent variable (price) is depicted on the y-axis and the dependent variable (supply/demand) is depicted on the x-axis.

The anchor example for **descriptive charts without domain-specific terms** (lower left panel in Table 2) is a simple visualization visualizing a contract between two individuals. The design elements (here: arrows) show the relationship between the two contract partners. The terms used in the chart are rather everyday language than specific economic terminology. In consequence, no domain knowledge is needed to interpret the terms or the design elements.

For **charts with domain-specific terms**, the interpretation of the design elements does not necessarily require domain-specific knowledge, while understanding the terms used is necessary to grasp the whole chart. The anchor example (lower middle panel in Table 2) is a visualization of the possible economic effects of government spending on refugees. The design elements (arrows) can be interpreted as “consequence of”, the terms used, e.g. “Investitiongüter” [capital goods], “Konsumgüter” [consumer goods], are economic terminology.

The anchor example for **charts representing domain-specific principles** (lower right panel in Table 2) is a visualization of the model of the circular flow of income, which visualizes economic interrelations between different actors (state, bank, households, companies). The design elements (arrows) are labelled with economic terms and visualize the interplay between the actors. The interpretation of this chart is difficult without comprehensive knowledge of the terms used and the underlying economic principles.

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3.2.2 Graphs and charts in textbooks

In the five textbooks, a total of 450 visualizations were identified as logical pictures (graph or chart). On average over all books, there is one logical picture every 3-4 pages. Of these visualizations, 276 were rated as graphs, and 174 were rated as chart. An overview of the textbooks can be found in Table 3.

Tab.3: Overview of logical pictures in different economic textbooks

	Grade level	Pages	Logical pictures Total	Graphs	Charts	Page/ Logical Picture Ratio	Correlation between page number and domain specificity (Kendall's Tau)
Book 1	8-10	312	87	50	37	3.6	0.24 (p = .004)
Book 2	8-10	280	49	26	23	5.7	0.28 (p = .016)
Book 3	8-10	213	87	32	55	2.4	0.26 (p = .002)
Book 4	8-10	312	85	67	18	3.6	0.17 (p = .040)
Book 5	11-12	455	142	101	41	3.2	-0.19 (p = .004)

In the following Figure 8, we provide an overview of the number of graphs and charts in relation to their domain specificity.

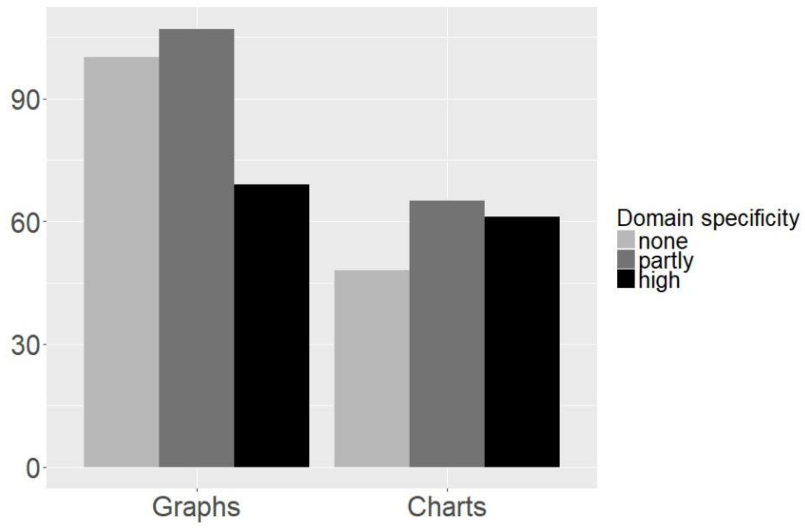

Fig. 8: Number of graphs and charts in economic textbooks of the secondary level, subdivided according to the domain-specificity

In total, 100 graphs (in comparison 48 charts) were rated as descriptive with no domain-specific terms, which should, therefore, be understandable without content/prior knowledge. 107 graphs (65 charts) were rated as partly domain-specific, due to the use of domain-specific terms. 69 graphs (61 charts) were rated as highly domain-specific, due to their visualization of economic principles. To explore whether the domain-specificity raises over the course of a school-year, we analyzed the correlation

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between domain-specificity and page number (assuming that a book would be used in a rather linear fashion). For all grade level 8-10 textbooks, a correlation between 0.17 and 0.27 was found and therefore more domain-specific graphs are used later in the books. In the textbook for the upper secondary level, domain-specificity and page number correlated negatively (r = -0.19).

4 Study 2: Interview study

4.1 Methods

4.1.1 Participants and data collection

For the second study, we interviewed a sample of N=10 economics teachers in higher secondary schools (Gymnasium). Due to the new subject (see above), teachers had only taught economics at the upper secondary level (grades 11/12) at the time of this study. In consequence, we interviewed these already experienced teachers. Although the teachers represent a convenience sample, they differ in age (ranging from 34 to 63) and their second/third subject (languages, math, geography, history, physical education).

After a short introduction, where different logical pictures from the textbooks were shown as examples, the teachers were asked about the quantity of usage in teaching, their purpose/learning aims when using logical pictures, the importance of logical pictures for teaching, as well as relevant student competencies and difficulties. Each interview lasted between 20-45 minutes. All of the interviews were carried out by the first author, audiotaped and transcribed shortly afterwards. Although the questions varied depending on the course of conversation and the use of logical pictures of individual teachers, an interview guideline was used (see Appendix).

4.1.2 Content analysis procedure

The transcripts were analyzed applying qualitative content analysis (Kuckartz, 2016), using the software MAXQDA. Initially, we coded the answers according to three main categories that emerged from the guiding questions (use of logical pictures, competencies and challenges). For the use of logical pictures, the following subcategories were created inductively: use on average, importance and rationale for usage/learning goals. For competencies and challenges, we established subcategories deductively based on already established challenges and competencies in the literature, e.g. mathematical competencies (e.g. Ludewig, Lambert, Dackermann, Scheiter, & Möller, 2019), reading comprehension (e.g. Scheiter, Schüler, Gerjets, Huk, & Hesse, 2014), integrating multiple representations (e.g. Kozma, 2003), prior knowledge/background knowledge (e.g. Nitz et al., 2014); other subcategories were inductively supplemented based on the answers of the teachers (e.g. standardized description). An overview of the categories (and results) can be found in Table 4. For reasons of readability, we will only show the English translations (by the first author) of relevant quotations (the original German versions are available upon request).

4.2 Results

Tab.4: Overview of interview results

Category	**Rating / Subcategory**
Use on average	Every lesson (2/10) Every second lesson (5/10) Every third/fourth lesson (3/10)
Importance	Important or very important for teaching economics (10/10)
Rationale of usage and learning goals	Derive a problem, introduce a topic, activation of prior knowledge or fact-checking (4/10) Visualize economic principles and relationships, model thinking (7/10) Methods training, critical evaluation skills, graph reading skills (6/10) Place topic in larger context, structure domain knowledge, overview (5/10)
Competencies	Reading comprehension (5/10) Mathematical/logical abilities (5/10) Integrating multiple representations (3/10) Content and background knowledge (6/10) Critical thinking and evaluation (6/10) Standardized description/analysis (4/10) Construction of logical pictures (4/10)
Challenges	Mathematical/logical abilities (7/10) Precision and concentration (4/10) Connecting logical picture with tasks and identifying key points (7/10) Critical evaluation (4/10)

4.2.1 Quantity of usage and relevance of logical pictures

Teachers use graphs and charts regularly for their teaching, from every hour to once a week. For the teachers, the quantity depends on the content of the lesson, some topics, for example markets, are always taught with graphs.

> "So if we examine market and prices, it's in every hour, even in the practice phases, but otherwise perhaps on average once a week." (Interview 9, #00:03:03-5#)]

Teachers consistently deem graphs and charts as important to very important. They justify this both based on the discipline/subject content (e.g. thinking in models and data in economics), the advantage of logical pictures for learners (e.g. different forms of access to content, multiple representations), but also the advantages from the

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teacher's point of view (e.g. using charts as a way of securing results/checking understanding).

> "Yes, they [the logical pictures] are from my point of view one of the most central sources, even more so than others, I think the economy or economic education is characterized by the fact that statistical analysis plays a major role, and thus logically […] logical pictures are central" (Interview 3, #00:07:12-2#).

4.2.2 Rationale for usage and learning goals

Teachers use different types of graphs and charts, depending on content and learning goals. Descriptive graphs are used to derive a problem, introduce a new topic or activate prior knowledge (Interview 10, #00:15:08-9#).

More complex graphs (e.g. supply and demand graphs, Lorenz curve etc.) and charts (e.g. circular flow of income), are used to develop economic knowledge, i.e. to learn about economic principles, to apply model thinking and to assess interrelations and processes.

> "… this supply and demand graph to somehow see changes from one element to the whole, so […], the supply increases the demand decreases, what happens then […], or if there is a price change due to tariffs […], what effect does this have?" (Interview 5, #00:05:22-2#)

In a similar vein, a teacher described the circular flow of income as a good visualization to place the topic in a larger context and to get an overview regarding the economic system:

> "Well, let's take this circular flow of income as an example, if you introduce the system of economics, what instances there are, which actors are active, and this is gradually developed in a chart, then of course [...] it is good for clarity, and ultimately, like everything we do in class, it ensures learning success." (Interview 6, #00:03:59-3#, #00:04:16-1#)

Teachers also use certain logical pictures to train methodological competence, to work with data, e.g. to check facts/hypotheses, to foster graph comprehension/statistical literacy and critical thinking competencies (Interview 5, #00:05:22-2#).

4.2.3 Relevant competencies

Reading and text comprehension is regarded as a basic (but not unimportant!) prerequisite by the teachers, to understand the relevant part of graphs as well as accompanying text and tasks:

> "So what I basically notice in teaching economics, as in any other lesson, is that text, language ability, is the basic prerequisite. […], it first needs a lot of language skills to understand the axis label, the heading in context." (Interview 6, #00:07:40-8#)

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To be able to work with logical images – especially with graphs in economics, students need certain *mathematical competencies* (e.g. absolute versus relative numbers). It is also important that they recognize in which unit of measurement the values are displayed and which concept is displayed on which graph axis (*graph reading competencies).*

> "…so exactly with these supply and demand curves [...] they must be able to recognize what is represented there, so just they must look at the numerical values, what is represented on the x- y-axis, in which unit of measurement are these values represented…" (Interview 5, #00:09:17-0#)

According to the teachers, students also need the ability to *integrate information from multiple representations*. This includes to be able to "translate" between different external representations:

> "If you introduce logical pictures you say you can display something as graph, as table, as flow chart and as text and they [the students] have to be able to jump back and forth between these display forms." (Interview 6, #00:05:35-0#)

Content and background knowledge were also deemed important by the teachers for analysis, interpretation and evaluation. As content knowledge, they explicitly mentioned the relevant keywords in the logical pictures (e.g. gross domestic product, aggregated income…) as well as "historical" context knowledge (e.g. to explain economic development over a longer period of time). Some teachers noted that the amount of expertise needed depends very much on the graph and task and cannot be generalized.

> "Do I need economic knowledge? That depends, with the supply and demand curves yes, I need economic knowledge. If I have a statistic on GDP, first of all, to understand the visualization, I don't need quite as much economic knowledge, of course I apply it later [...] At the second step I need it, clearly" (Interview 4, #00:06:31-2#, #00:06:32-9#)

Some teachers point out that students need to be able to *construct logical pictures*. One teacher regularly asks the students to construct a flow chart from a given text, whereas another teacher instructs his students to draw graphs from data (e.g. the course of unemployment rate, price increase and economic growth since the 1950s).

According to the teachers, *critical evaluation* of the content and the visualization is a crucial ability. Therefore, they expect their students to examine logical pictures and their content regarding their possibility to influence the reader on different levels. As examples of what to analyze critically, they cited design choices (e.g. manipulation through a limited display of data or displaying axis in different units etc.), the publisher/origin/source of graph and data, their underlying interests as well as the deconstruction of common economic models (that are often depicted graphically).

> "…on the other hand, it is important that you can also somehow evaluate diagrams from different sources, depending on who made them, that's always an

> important part of it. A critical approach to logical pictures." (Interview 1, #00:04:33-8#)

The teachers assessed it as important that students use a *standardized description/analysis procedure* to deal with graphs. In addition to an introductory sentence, teachers expect three different requirement levels: (1) describing the graph, (2) analyzing (e.g. what is important, what is not important for a question at hand), (3) evaluation (where does the graph come from, who published it and what could be the interests behind it?):

> "If you divide this into three parts, okay, I have the description level, I have the classic interpretation level, which then means that from this graph you can clearly see that this and that will happen or is predicted and the third part is than with what intention was the logical picture published by whom" (Interview 10, #00:13:12-6#)

4.2.4 Difficulties and challenges

According to the teachers, students often view a graph or a chart as a single representation and fail to see *connections to other representations or to the domain task*. As a consequence, they struggle to identify key points of a logical picture, cannot separate important and unimportant information and lack understanding:

> "[…] the analytical competence, so how do I read the thing and what does it really mean what I see there, and can I summarize it in one sentence and if I can't do that, it often shows that they simply haven't understood what the axes say, or what the percentages or the numbers as a whole are supposed to say, that's actually rather the problem" (Interview 1, #00:06:55-2#)

The teachers also identified *critical evaluation* as one of the more challenging parts of working with logical pictures (in line with requiring it as a competence, see 4.2.3). Students are not always able to detect manipulation (e.g. through a limited display of data or displaying axis in different units) and they do not always include the source of the graph/chart in their analysis.

> "Only a fraction of students achieves this third level […], namely to work out this interpretational sovereignty so that their opinion is not externally determined. That, of course, is what we want, the responsible citizen." (Interview 10, #00:13:12-6#)

Among the problems that teachers face when working with quantitative visualizations in economics are *missing mathematical abilities*. According to the teachers, students are not always able to calculate percentage scores, distinguish absolute from relative numbers, calculate the median or average or work with index numbers although this is identified as a crucial competence (see 4.2.3).

> "Then what I really notice is that some of them really lack the rudimentary abilities [...] that they highlight certain numbers by putting them in relation [...] and

> then I notice that sometimes it's hard for them to calculate the percentage scores, [...] not everyone is able to use the rule of three." (Interview 7, #00:08:17-5#)

Finally, some teachers point out that students are not *precise* enough. When analyzing a graph, they might sometimes miss details, e.g. the unit in which a certain parameter is displayed. The teachers attribute this kind of challenges to *concentration* rather than to conceptual understanding or lacking mathematical abilities.

5 Discussion

The objective of these two studies was to show how logical pictures are used in secondary economic education by a) analyzing logical pictures in textbooks with regard to their form (chart or graph) and their domain-specificity and b) interviewing economic teachers about their experiences.

With our study, we distinguished between different forms of logical pictures (e.g. Harris, 2000; Kosslyn, 1999), and, between different levels of domain-specificity. The latter adds another layer to the already existing frameworks as it allows for a separation of descriptive representations that visualize (economic) content with usual graphs or charts from visualizations which show economic principles.

This separation is helpful in understanding the different abilities and challenges that learners face in the classroom: whereas certain reading rules are necessary for all visualizations, content knowledge and more specific reading rules seem to be necessary for the "more domain-specific" visualizations and thus should be addressed in secondary economic education in order to support learners to become domain experts. The fact that not all logical pictures in a textbook are domain-specific can be explained by the nature of the subject: it is the first time students are confronted with economic concepts. In consequence, some logical pictures (more in earlier sections of the textbooks as the correlations between page number and domain-specificity overall shows for the earlier text books) rather use everyday language – and, accordingly, are not rated as domain-specific.

As described by the representational dilemma (Dreher & Kuntze, 2015; Rau et al., 2017), the teachers in the *second study* explain how they use logical pictures not only for the development of domain knowledge (learning from representations) but also to develop strategies to learn *with* logical pictures. They expect their students to use a strategy (e.g. standardized description) for their analysis.

The teachers mentioned some of the abilities and challenges that are already established in graph comprehension and representational competence literature, e.g. reading competence (e.g. Åberg-Bengtsson & Ottosson, 2006) or (basic) math competencies (e.g. Ludewig et al., 2019). Comparable to findings in science education (e.g. Cook, 2011; Kozma, 2003), they mentioned the need to connect multiple representations, to switch between different representations and to construct their own logical pictures

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(based on data or text). Furthermore, this study also confirms the need for content and background knowledge (e.g. Stern, Aprea, & Ebner, 2003).

Teachers also argued that the evaluation of logical pictures is a very important step in the classroom. Accordingly, one of the central challenges for students (from the teachers' perspective) is to identify the relevant key features of a logical picture for the task at hand and to critically evaluate the visualization also in light of purposefully using statistics to influence the reader. This is, above all, important as graphs are used as plausibility tools in texts (Isberner et al., 2013) and might tempt readers to focus less on the text (Ögren, Nyström, & Jarodzka, 2017).

Overall, both studies showed that logical pictures are important for economic education. The high number of graphs and charts in all textbooks corresponds to their relatively frequent usage in authentic classroom settings. The fact that there are more graphs than charts in the textbooks might be connected to the demand for more "mathematical" competencies and the prevalence of math-related challenges the teachers described in study 2. Furthermore, the different levels of domain-specificity in the textbook analysis might correspond to different demands on students. For example, for descriptive visualizations, students might need graph reading and analytical competencies, while more conceptual understanding and content knowledge would be a prerequisite for more domain-specific logical pictures.

5.1 Limitations

When interpreting these results, however, it is important to keep the limitations of the two studies in mind: First of all, we only interviewed teachers who were teaching on the upper secondary level. However, we argue that it is reasonable to assume that most of the described competencies and challenges are accurate for different grade levels in a broad sense whereas details (e.g. which mathematical competencies do students need exactly?), might differ between grade levels (e.g. basic math competencies and graph reading rules might be more relevant in earlier grade levels whereas conceptual understanding and more complex math / statistical knowledge might be expected at the upper secondary and university level). Thus, the differences between the competencies needed could be an interesting array for future research.

Although we analyzed all textbooks available for grammar schools in south-western Germany, it is not a representative sample for all secondary economic education textbooks in Germany – the same is true for the teacher-interviews. Since we were only able to conduct interviews with a convenience sample of teachers, the relevance and quantity of usage of visualizations might be overestimated (teachers that use many visualizations and consider them important are much more likely to participate in a voluntary interview). However, we attempted to find different teachers with varying teaching experience and from multiple backgrounds (concerning their other school subjects) to allow for some variability among the teachers. Lastly, we analyzed the instructional material and interviewed teacher about their use, i.e. we focused on the teaching input. However, for now, we were not able to observe the actual use in the classroom, which could be the next step in future research.

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5.2 Implications and further research

Despite the limitations, the two studies emphasize the importance to distinguish between different logical pictures such as graphs and charts and regarding their domain-specificity as they are powerful tools to explain and visualize economic concepts (Hey, 2005; VanderMolen & Spivey, 2017). Although they are used frequently in teaching, the teacher interviews indicate that students need support to understand and evaluate the logical pictures. At the same time, as different logical pictures are offered in textbooks and since experienced teachers report different challenges when using them in the classroom, it is advisable to include the topic in teacher education for social sciences as well.

In addition to these practical implications, there are different avenues for future research. First of all, it would be necessary to replicate the findings for different grade levels and other local contexts as well as to empirically confirm the necessary students' competencies and the challenges identified.

There is also a need to examine how to foster representational competence in the social sciences – e.g. to design material in a way that connects graph-text and task (as done for other domains in multimedia research, e.g. Scheiter & Eitel, 2015) or to design trainings where learners use certain graph and text-reading strategies (e.g. Seufert, 2019) or construct their own representations (e.g. Stern et al., 2003). As especially critical evaluation is difficult for students, it would be interesting to analyze how teachers (and/or technologies) can support students in that regard.

From our findings, it is clear that such interventions should be adapted to the domain-content that is taught with the representations, since – especially for more domain-specific graphs and charts – content and representation are to be seen as integrated teaching material.

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Appendix

Interview guideline questions

- How often do you use logical pictures in teaching economics?
- What graphs/charts are you using in teaching economics?
- What is your goal when using logical pictures in economic education?
- In what part of the lesson are you using logical pictures?
- How important are logical pictures for teaching economics?
- What competencies are necessary for students to work with logical pictures in economic class?
- What difficulties do students have when working with logical pictures?
- How do these problems manifest?
- In your opinion, how could the work with logical pictures be improved?
- Do you have additional thoughts regarding logical pictures in teaching economics?
- Do you have any open questions?

Sources of anchor examples

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