**CREATING THE DE | INFORMED CITIZEN**

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**Abstract**: The goal of this article is to deepen our understanding of the entanglement of mathematics in the early COVID-19 discourse in Germany. A theoretical reflection and critique of the concept of mathematical literacy precedes and prepares an exploratory analysis of four concrete instances of expert-layperson communication in the form of media contributions. The theoretical reflection enriches Fischer’s (1984, 2001, 2006, 2012) perspective on citizenship education by drawing connections between his work on the implicit and explicit culture of mathematics and other well-known theories in critical mathematics education. These insights together with the analytical repertoire of Laclau & Mouffe’s (2014) discourse theory provide tools and concepts which are used to describe different kinds of expert-layperson communication found in the data material. The empirical analysis details example cases in which mathematics plays a crucial part in the constitution of the roles of and relationships between experts and citizens resp. laypeople. We conclude that phenomena found in our material point to a general basic dilemma that is missing in explanations and suggestions on mathematics literacy in mathematics education discourse.

## Prologue: motivation and rationale of the project

In early March 2020, COVID-19 began affecting Germans’ professional and private lives: What had previously been mere advice to refrain from work-related trips and relocate work into home office was converted into official directives; many people had to find new ways of collaborating with colleagues and of fulfilling their professional duties at a distance, while, at the same time, being confronted with a novel, uncertain situation in their private lives that they had to make sense of and adapt to.

It soon became noticeable that mathematics was gaining central importance in public communication about this unprecedented situation: The so-called ‘corona-crisis’ permeated every aspect of life and dominated every news broadcast in Germany. Nearly all of these reports on COVID-19 – also labelled ‘Corona’ by German media – featured numbers and/or mathematical concepts such as exponential curves. Family members and friends, even those who otherwise tended to distance themselves from mathematics, started to share the „flatten the curve”-slogan on Facebook, recited numbers and underlined the importance of understanding exponential growth.

Given this unusual surge in mathematical communication within public discourse, our working group began to hold regular online-meetings to discuss media reports about the pandemic situation and to generally make sense of the above described developments. A first focus of our discussions was the importance of mathematics for everyday life, i.e. the role and significance of *mathematical literacy* in the observed communications:

* At first glance, the situation and discussion surrounding the COVID-19 pandemic appears to have rendered evident the importance of (understanding) mathematics for everyday life. But has it also acted as an incentive for (normal) people to engage with mathematics (more)? Has it somehow benefitted efforts to foster reflective citizenship on the basis of mathematical literacy?

Follow-up questions that immediately come to the minds of mathematics educators and mathematicians alike are:

* Are the mathematical explanations provided by the media mathematically adequate?
* Is more mathematical depth necessary / are explanations too superficial?

Questions about the role and importance of mathematics in normal people’s lives have since been addressed in a paper by Kollosche & Meyerhöfer (2021), who also focussed on German media reports. They investigated if the early German COVID-19 debate could be reasonably well understood on the basis of average to good mathematical literacy. Using the framework of ‘expert-layperson communication’ by Fischer (p. 403 ff.) and Skovsmose’s concepts of “reflective knowing” (p. 403) and “mathemacy” (p. 404), they considered a form of ‘critical mathematical literacy’ (p. 404). The two authors do not just doubt the mathematical adequacy of certain models that were frequently employed in media reports: “In the case of the exponential function (…) the model used appears to be simply misleading.” (p. 412). They conclude that in the specific case of the debate surrounding the COVID-19 pandemic, mathematical concepts became relevant which “cannot be understood by mathematical laypersons to an extent that would allow for the evaluation of (…) expert knowledge” (p. 414). In other words, doubt is cast on the mathematical adequacy of some of the discussed concepts as well as on the didactical adequacy of any presentation of the ‘actual’ mathematical concepts underlying the scientific discourse in epidemiology, as they appear to be “out of reach” (p. 410) of adressees with basic mathematical knowledge according to current German school curricula. Overall, questions are raised about the employability of mathematical knowledge when tackling (at least certain) real-life problems and about the role and relevance of mathematical literacy.

A second focus of our working group’s discussions, which arose from our background in critical mathematics education, was the use of mathematics within public debates (cf. Pais, 2017, Kollosche, 2017). In early spring 2020, the German public debate about the pandemic situation witnessed frequent changes in the mathematical elements of choice used to portray the pandemic situation and to justify concrete actions for its handling. Political measures that only weeks ago had been unimaginable were implemented on the (alleged) basis of (mathematical) expert knowledge. Questions that were inspired by these observations concerned the constitution of meaning in public debates and related discourse strategies, power relations, as well as ideological elements:

* What role do mathematical elements play in the observed discours(es)? Are mathematical elements employed to create a specific framing of the situation at hand or the argument at stake?
* What image of mathematics is conveyed in the communication and what relation does it establish between the speaker and the addressee?

Jablonka & Bergsten (2021) investigated the early German COVID-19 debate from a discourse-theoretical perspective. They identify and describe four strategies for construing the ‘corona crisis’ and for generating compliance using certain mathematical elements that the authors refer to as “numbers” (p. 2). They suggest that making such discursive strategies explicit in education could help enable critical reflection of the use of mathematics in public debates.

In our working group’s discussions, we shared the perception of shifting relationships in the triad of *politicians*, *experts* and *citizens*, or, in educational terms, variations in the *expert-layperson relationships* (cf. Fischer, 2001) that manifested in different media contributions. The expert-layperson relationship is a center-piece of Fischer’s conception of citizenship education, which revolves around the education of *reflective citizens* and which we will elaborate on later. Inspired by these observations, we formulated two initial research questions:

* *How is (the use of) mathematics woven into the discursive formation of the expert-layperson relationship within the early German COVID-19-discourse?*
* *How can the citizens’ assigned sphere of influence in connection with mathematics be described?*

In discourse-theoretical terms, the occurrence of different constructions of the roles of discourse participants can be interpreted as an instance of Laclau & Mouffe’s (2014) *discursive struggle*, which is linked to the idea that crises create opportunities to shake up sedimented discourses.

Central to Laclau & Mouffe’s work, which provides analytical categories to describe discursive structures, is the idea that meanings are never completely fixed, thus always subject to change. The negotiation of meanings takes place within constant discursive struggles. Laclau & Mouffe reject a distinction between discursive and non-discursive practices and understand “the whole social field […] as a web of processes in which meaning is created” (Jørgensen & Phillips, 2002: p. 27). Signs obtain their meaning trough constructions of chains of equivalences or through assertions of differences. Meaning is (re-)produced through the articulation and recomposition of *elements*, i.e. signs whose meaning is not yet fixed. By establishing relations of equivalence and difference between elements, their range of possible meanings is modified. Within an articulation, their ambiguity is reduced and so meaning becomes partially fixed: elements become *moments*. The structure resulting from *articulatory practices* describes the *discourse*. Privileged discursive points of this partial fixation are called *nodal points*. The meaning of a nodal point[[1]](#footnote-1) is constituted by the arrangement of its moments around it. Vice versa moments get their meaning from the relation to the nodal point and each element is fixed as a moment by its relations to other elements. Through this arrangement other possible meanings of the discursive elements are excluded. The excluded possibilities form the *field of discursivity*. Different discourses can (partially) fix different meanings to the same nodal point. In this situation of *struggle* each discourse is part of the field of discursivity of the other. Each discourse mutually excludes the meaning the other discourse tries to fix – an antagonism manifests:

[A]ntagonism involves the exclusion of a series of identities and meanings that are articulated as part of a chain of equivalence, which emphasize the 'sameness' of the excluded elements. As the chain of equivalence is extended to include still more elements it becomes clear that the excluded elements can only have one thing in common: they pose a threat to the discursive system. (Howarth & Torfing 2004; p. 15-16)

With this analytical repertoire, we are able to formulate the first research aim for the analysis of media contributions:

1. The *first aim* of the analysis is to reconstruct the discourse(s) in our material in the above described sense, i.e. we will reconstruct important moments and nodal points in each one of the selected media pieces.

Such a discourse reconstruction establishes a basic understanding of the discursive structure. Still, the categories provided are by themselves not sufficient for our analysis, because they are not specific to the mathematical context. We therefore additionally draw on literature on mathematical literacy and its criticism, which we present in a theoretical reflection in section 2. The concept of mathematical literacy is part of a broader discursive struggle surrounding the notion of expert-layperson relationship and, in fact, it was not so much ‘well-established’ conceptions of mathematical literacy rather than their criticism which provided valuable insights for understanding the discourses in question. In the theoretical reflection, we therefore introduce a conceptual alternative to mathematical literacy by Roland Fischer (1984, 2001, 2006, 2012). Relating mathematical literacy to his distinction of implicit and explicit culture of mathematics allows us to link a critique of mathematical literacy to paradoxes of mathematics education that have been described in critical mathematics education literature. Throughout the analysis, Fischer’s theoretical concepts and their relation to ideas from critical mathematics education sensitized us for discursive logics at play and aided us in the description and interpretation of phenomena, which are specified in our second research aim:

1. The *second aim* of our analysis is to investigate, what meaning the elements *citizen*, *layperson*, *expert* and *mathematics* have in each media piece and how they are related to each other with a focus on the following topics:
* the relationship and communication between experts and laypeople
* the sphere of influence of citizens in connection with (the use of) mathematics
* the role of mathematics for each protagonist (experts, laypeople, citizens) in the discourse

After the theoretical reflection in section 2, we describe in section 3 how we selected media contributions for the analysis, we situate these media contributions within the local German COVID-19-discourse and we explain our approach to analysing the selected materials. In section 4, we present the main results of the analysis and discuss our findings in relation to the concepts and ideas presented in section 2. In section 5, we will reflect democratic educational ideals before the background of our findings. Our findings point to the existence of a general basic dilemma that is not addressed by current discussions of the concept of mathematical literacy.

## Mathematical literacy and its relation to citizenship

The point of departure of this theoretical reflection is the concept of mathematical literacy and, in particular, the well-established view in mathematics education that mathematical literacy is crucial[[2]](#footnote-2) for citizenship.

##  The OECD’s understanding of mathematical literacy

One widely accepted definition of mathematical literacy comes from the OECD:

**PISA 2012 Definition of Mathematical Literacy**: *Mathematical literacy* is an individual’s capacity to formulate, employ, and interpret mathematics in a variety of contexts. […] It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens. (OECD, 2010, p. 4; emphasis in the original)

Underlying this definition of mathematical literacy is an idea of citizenship education that is based on the vision of strengthening democracy through systematic education of future “good” citizens, where part of “being good” is the attainment of mathematical literacy.

As Andrade-Molina (2017, 2018) highlights, these definitions and descriptors are not neutral, but postulate particular access positions for the attainment of mathematical literacy. They are used to describe what positions are considered advantageous or disadvantageous for becoming a good citizen, thereby not just qualifying populations as privileged or “at-risk” in terms of becoming “good” (citizens), but actively creating and distributing these positions.

It has also been pointed out that the OECD’s understanding of citizenship education in connection with mathematical literacy contains assumptions about the type of contribution mathematics makes in modern western societies and about a citizen’s role in engaging with and judging these mathematical elements: Firstly, the OECD’s notion of mathematical literacy is often brought up in connection with the idea of “developing human capital” (Jablonka, 2003, section 3.1). Secondly, it is linked to the image of an intrinsic power of mathematics, to a view of mathematics as having “a life on its own, independently from the human beings that both have invented and used it” (Valero, 2007, p. 1). Accordingly, equipping citizens with mathematical skills “empowers” them by raising their market value and by making them wielders of the powerful device that is mathematics. We agree with Valero’s (2007) objections against the conceptualization of power underlying this “empowerment” as intrinsic or permanent characteristic and her proposition of an alternative view of “power as distributed positioning” (p.9).

Biesta (2011) formulates a related critique about the OECD’s conception of citizenship education (and similar “socialization conception[s]” (p. 142)) for being based on “the idea that it is possible to know what a good citizen is, so that the task of citizenship education becomes that of the production of the good citizen” (p. 141). He favors to conceptualize the position of the citizen within democracy to be relational and in constant transformation and calls for an abandonment of the understanding of citizenship as a positive, definable identity.

In view of the mentioned critiques of the notion of citizenship education and its relation to mathematical literacy, we are not interested in asking how or if mathematical literacy contributed to understanding the COVID-19 situation or what kind of mathematical literacy would have been needed to enable people to fulfill the role of ‘reflective citizens’ (cf. Kollosche & Meyerhöfer, 2021). In this paper, we ‘invert’ the question by asking how mathematics is entangled in formatting and defining citizenship.[[3]](#footnote-3) In order to unravel the role that mathematics plays for citizenship, we now introduce Fischer’s conceptual alternative to mathematical literacy, which focuses on the relationship between *citizens*, who are conceptualized as *laypeople*, and *experts*, and take closer look at the formation of the expert-layperson relationship, which describes a possible concretization of the role of ‘reflective citizen’.

##  Fischer’s ideal of the reflecting layperson

In German-speaking countries, official descriptions of mathematical literacy follow the PISA-framework but complement it with ideas of ‘Allgemeinbildung’ (approx.: general education) that have been elaborated specifically for mathematics education and its relation to citizenship education by Heinrich Winter and Roland Fischer (see Vohns, 2017). Fischer (2001, 2012) formulates an alternative proposal of thinking about citizenship education which centers around the problem of communication between *experts* and citizens resp. *laypeople*. He considers *expert-layperson communication* as constitutive for the functioning of the division of labour in democratic societies. Fischer articulates his educational ideal in the concept of the reflecting layperson, who is capable of making well-founded judgements and decisions. He distinguishes two areas of knowledge relevant for laypeople/citizens: (1) basic knowledge (of mathematical concepts, terms, forms of representation) and skills, as well as (2) knowledge for reflection (on the meaning of mathematical practices) (Fischer, 2001, p. 154). Reflection requires specific knowledge of the use of mathematics in decision-making. As contributions of mathematics to social processes of negotiation and argumentation may not always be readily apparent, reflection has to take implicit mathematics into account.

In our reading of Fischer (2006)[[4]](#footnote-4), *knowledge for reflection* includes knowledge about the relationship between mathematics and society. In this section, we will give a brief overview of some aspects of this relationship that were described by Fischer and other scholars in critical mathematics education.

Fischer (2006) discusses the social relevance of mathematics and its contribution to modern western culture. He distinguishes between *implicit culture*, by which he designates “our norms, value systems, patterns of organization, […] civilization and regulation of modern societies”, and *explicit culture*, “which is processed in the consciousness of people, about which we speak, negotiate and make decisions according to important / unimportant” (p. 316). The following two sections adopt the distinction between implicit and explicit culture. In each section, an initial explanation is given of some of Fischer’s ideas on the contribution of mathematics to implicit and explicit culture respectively. This explanation is then enriched with a summary and synthesis of relevant contributions from other authors in critical mathematics education (CME).

### The contribution of mathematics to implicit culture: de|mathematization

Mathematics has the power to “*materialize*” abstract issues and thereby acts as an “important medium of mass communication” (Fischer 2006, p. 317). Materialization is an effect of *mathematization* and happens through the creation of a system of signs which allows to materially fix abstract issues in the form of symbols, giving these issues a concrete shape that is readily perceivable.

The materialization of these abstracts is important, because thereby they gain that status of existence, which makes them able to be content of communication among many people. […] [M]aterializing […] contributes that people have the impression to know what they are talking about. (p. 317)

Materialization makes possible not just the representation but also the manipulation of abstract issues. The manipulation of mathematical materializations is based on a system of rules and can be described as an interplay of representing and operating. Mathematical practices thus can be seen as both facilitating the process of abstraction and endowing the abstract with reality. They play a crucial role in organizing social systems as they enable the negotiation of abstract issues of importance in social systems in which face-to-face communication is not possible. This role of mathematics as facilitator of communication is supported by its “systemicity”: Mathematics is a “coherent building of thoughts” governed by fixed rules which was designed to be contradiction-free and endowed with a “claim to totality”. As such, it “offers a basis for a minimal consensus” and contributes to communicative stability by bringing a sense of security to communication (Fischer 2006, p. 317-318).

Skovsmose describes the formatting of human practices and life conditions through mathematical insights and techniques (Skovsmose, 2014, p. 442). Mathematization is seen by him as intervening into the structural arrangements of human life and as re-organising our life conditions. Within the CME-discourse, this aspect is termed the *formatting power of mathematics*. Work on this topic often argues for not displacing the political from mathematics education, referring to both the research discipline and practice. Ernest (2010), who follows this view, suggests that a primary concern of a critical mathematics education is to foster understanding of the formatting power of mathematics. However, in this view mathematics holds two seemingly contradictory roles in that it is both a means of empowerment (through knowledge), and a tool of oppression (Sriraman, Roscoe, & English, 2010). These contradictory roles arise from (1) the *paradox of citize*nship (Skovmose & Valero, 2002, p. 384-387), which is the contradiction between the educational aims of preparing students to be active, autonomous and critical citizens and of ensuring the individual’s compliance with the reigning social order, and (2) the *duality of societal importance* of mathematics: „Mathematics is a means which we can use, and simultaneously it is a system, to which we are subject“ (Fischer, 2006, p. 318). Fischer, in agreement with Skovsmose & Valero (2002), acknowledges that „in modern societies people are socialized in a way such they submit themselves voluntarily” (p. 318). Valero (2007) argues in a similar vein that mathematics education contributes to the governance of citizens through socializing them into a system of reason, that stands for accepted forms of characterizing and organizing the world. Overall, there seems to be agreement, that mathematics does not just represent abstracts or manipulate signs, but constitutes the desirable and the appropriate and so helps to regulate the behaviors of individuals by framing their possibilities of participation.

This effect is exacerbated by an ongoing and self-accelerating societal process: „Permanently new means are developed, especially to handle the complex system, and exactly these means can become parts of the system, thereby increasing its complexity.” (Fischer, 2006, p. 318). *Mathematization accelerates*. The ever-growing complexity of the system increases the demand for mathematics and, in consequence, the amount of mathematics society submits itself to. Straehler-Pohl (2017) employs the terms *mathematisation* and *demathematisation* to describe this phenomenon. The two concepts are intended as antagonistic phenomena which stand in a dialectical relation to each other. The notation *de|mathematisation* signifies this type of relationship. Demathematisation denotes the disappearance of mathematics from ordinary social practice (Keitel, 1989, p. 10), its transformation into *implicit mathematics*. An increasing mathematisation reinforces demathematisation[[5]](#footnote-5). This takes place through the incorporation of mathematical knowledge into the production of objects and into the objects themselves (Chevallard, 2007, p. 58). Automated mathematical calculations for example make the consumption of mathematics much easier. Formerly complex and exclusive mathematical knowledge becomes accessible and applicable for consumers without any mathematical expertise of their own (Chevallard, 2007; Straehler-Pohl, 2007). Paradoxically, the progression of mathematization liberates the individual from the necessity of knowing mathematics (Straehler-Pohl, 2017).

The appearance of de|mathematized objects, that Sriraman, Roscoe & English (2010) shed light on, can be regarded as an exemplification of accelerating de|mathematization. In their 2010 paper, Sriraman et al. coin the term ‘*machinery-commodity duality of devices’* which denotes the twofold development towards a growing complexity of machinery, which is made possible through mathematical contributions (among others), while the commodity is increasingly concealing its inner workings, only displaying its utility to the user. Seeing mathematics as a device – for example for managing social organization – „the commodity is recognizable as ‘computational power’ which serves those who construct the technological world: architects, engineers, and scientists. […] mathematical theory, the machinery of computational power, [is] ‘turned away’ from the user, to shrink in size, and to grow ever more concealed” (Sriraman, Roscoe, & English, 2010, p. 631).

Regarding the question, what consequences arise from these insights with regard to the concepts of mathematical literacy and citizenship education, Fischer (2006) sees the need of equipping students with skills to critique mathematizations.

### The contribution of mathematics to explicit culture: the meaning of using mathematics

Fischer (2006) links the previously described phenomenon of de|mathematisation via the so-called ‘values of meaning and using’ to the division of labour: Following German sociologist F. H. Tenbruck, he distinguishes the *value of meaning* from the *value of using* of a discipline (in our case: mathematics) (Fischer, 2006, p. 319). While a discipline can have meaning in that it has “the power to give sense and orientation to humans and the society” (p. 319), usage can occur somehow independently from its meaning through the instrumental use of devices. Fischer goes on to argue for fostering reflection on the *meaning of using* mathematics in order to overcome what he calls “systems without consciousness” (p. 320) – rule-oriented social systems whose entirety or “wholeness is not collectively reflected” (p. 320). Such rule-based systems typically de-personalize and objectivise social organization and allow for a separation of the underlying rule system from the motives of the members of the social group, leading to a situation where “nobody has to care for the ‘whole’” (p. 320) anymore because the system will work even if every member only cares about their own issues (motives). Because of this, the system can develop an internal dynamic, a sort of life of its own. Mathematics can be viewed as a rule system governing a system without consciousness. In the case of mathematics, Fischer proposes that the invariant nature of mathematics, which by default serves to uphold the current form of the social system, could also be used to motivate alterations of this system (at least of non-mathematical parts). This could be addressed in a reflection of the meaning of using mathematics.

Fischer (2006) also points out a trend to give more rights to *systems without consciousness*. This trend was also observed by mathematics education scholars in the political sphere. Political approaches which reduce political decisions and reactions to unusual events to their technical complexities are said to be subject to a *technicization of politics*. Recent crisis-discourses (e.g. financial crisis and climate crisis) in particular showed a further intensification of the technicization of politics (Chassapsis, 2017; Pais, 2017) that could be described as profiting from an *ideology of certainty* (Pais 2017). In connection with mathematics, this ideology of certainty manifests in a “view of mathematics as an ‘above-all’ referee, as a ‘judge’, one that is above humans, as a non-human device that can control human imperfection” (Borba & Skovsmose, 1997, p. 17). This view entails the attribution of an intrinsic power to mathematics because of its supposed neutrality and objectivity, thereby implicitly suggesting it as suitable remedy to be employed in times of crises. Against this suggestion, Kollosche (2017) argues, that the financial crisis can be read to have been „caused by the mathematization of the world", which raises the question whether “more and more mathematics” is really the best strategy to come to a better understanding of crises (Kollosche, 2017).

Again, we may ask, what consequences to draw from this with regard to the concepts of mathematical literacy and citizenship education. Jablonka (2003) argues for a concept of mathematical literacy that includes „the possibility of critically evaluating aspects of the surrounding culture, a culture that is more or less colonised by practices that involve mathematics” (p. 76). This includes an awareness of the technicization of politics: „A mathematically literate adult should be aware of the danger of the substitution of political, philosophical, social and juridical arguments by numerical arguments that rely on complicated measures” (p. 93). Yasukawa (2010) highlights that it is not exclusively mathematics that formats implicit and explicit cultures, but that cultures – including neoliberalism and the military – are themselves involved in the production and shaping of mathematics.Therefore, it would be false to jump from a criticism of the role of mathematics in crisis-discourses to a condemnation of its contributions. Instead, reflection of the *meaning of using* mathematics in political discourses should be included as important part of mathematical literacy and, thus, citizenship education, to raise awareness for the interplay of the above described phenomena.

## Taking a closer look at selected media contributions

### Data

As material for our analysis, we chose four cases of German media contributions on measures against the COVID-19 virus that were aired in the months of March and April 2020, when case numbers first began to surge and the first lockdowns were implemented. The public discourse in Germany at the time revolved primarily around the following topics: scientific knowledge about the virus, the political response(s) to the crisis, behavioral guidelines and personal social responsibilities in a pandemic. Media contributions covering these topics typically featured several or all of the discourse elements that we wanted to look for, namely *citizen*, *layperson*, *expert* and *mathematics* (cf. second aim of analysis). However, we restricted our selection to contributions that were funded or aired by the German public broadcasting service. We did this because they can be considered a reliable source of information[[6]](#footnote-6), because people they designate as ‘experts’ would likely be acknowledged as such by most Germans, and because of their designated mission to inform the German population about relevant news and developments, which allowed us to assume that their communication is directed at the population in general (i.e. at laypeople), as opposed to specific subgroups (such as ‘workers’, ‘conservatives’, ‘researchers’, etc.). As we were interested in the range and variability of possible discourses, we picked media contributions which, on first glance, appeared to differ in relevant aspects (goal of communication, type of communication, issuer of communication). For pragmatic reasons, we decided to limit our material to four contributions. The selection is not intended to be representative in any way, but we tried to pick ‘relevant’ contributions which were either seen by a ‘large’ number of people (> 1 million within up to 5 days of publication) or whose contents were likely picked up by other media outlets.

Two of the selected media contributions were issued by two different science communication magazines. One media contribution is a press conference of the German federal [government agency](https://en.wikipedia.org/wiki/Federal_agency_%28Germany%29) and [research institute](https://en.wikipedia.org/wiki/Research_institute) responsible for [disease control and prevention](https://en.wikipedia.org/wiki/Preventive_healthcare) [RKI][[7]](#footnote-7). And one media contribution comes from the most watched German public broadcasting news magazine. All four cases make use of some form of mathematics in order to explain the situation and to justify measures taken by the German government.

1. The *Quarks* video (see 4.1) thematizes the „flatten the curve“-slogan that was popular in the beginning of the virus spread in Europe. [“Quarks” is a well-known and popular science communication magazine broadcast on German public television. Our selected video, however, was only available on Youtube.]
2. The *RKI Press Conference* (see 4.2) reports numbers of newly infected and death rates and acts as primary source of numbers for daily news reports. [The press conference was published on youtube on the news channel of German public broadcasting station *ZDF*.]
3. *MaiLab* (see 4.3) introduces the reproduction number as a mathematical figure of central importance and solves a modelling task in order to answer the question “How long will measures probably be in place?”. [To our knowledge, MaiLab’s contributions are exclusively published on Youtube. However, the channel is funded by FUNK which is part of the public broadcasting service.]
4. In the section of the *Tagesschau* that was analyzed (see 4.4), the prospect of a relaxation of measures is discussed, numbers are reported, experts are interviewed, the public's focus on numbers is commented on. [Tagesschau is the most watched German news magazine. It airs every day at 20:00 on German public broadcasting station ARD and online.]

Table 1 gives some basic information on the selected videos.[[8]](#footnote-8)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Quarks(Quarks, 2020) | RKI Press Conference(ZDFheute Nachrichten, 2020) | MaiLab(MaiLab, 2020) | Tagesschau(Tagesschau, 2020) |
| Publication Date[[9]](#footnote-9)  | March 21st, 2020  | Mar 25th, 2020  | April 2nd, 2020  | April 5th, 2020  |
| Length | 11:35 minutes | 29:45 minutes; Only the first 8:15 minutes were analysed | 22:25 minutes | 30:11 minutes; only the first 4:00 minutes were analysed |
| Popularity[[10]](#footnote-10) | March 25th: not on trending[[11]](#footnote-11) (any more); view count: 1,972,848 | March 25th: #16 on trending; view count: approx. 250,000 | April 3rd: #1 on trending; view count: approx. 1,709,379 | April 8th: not on trending; view count: approx. 780,000 |
| Type of media contribution  | Science communication magazines; aired via public service broadcasting | Press conference by the RKI; aired via public service broadcasting | Science communication magazine; aired on Youtube | Most watched German public service broadcasting news magazine[[12]](#footnote-12)  |
|  |  |  |  |  |

Table 1: Overview of basic information on the selected videos.

### Method

The selected videos were transcribed. The transcriptions indicated the current speaker and important graphics or headings that were shown in the video.

The textual analysis was conducted in the following manner: We first watched the videos and read through the transcripts, made a summary of its literal contents and noted down first impressions of the effects that the respective video achieves through stylistic decisions (e.g. tone of voice, look of presenter, background music, scene cut, etc.) each for ourselves. Second, we discussed the videos (resp. video segments) in a group of four and systematically coded important or recurring themes of the material. Code labels were taken from the material itself. We then reconstructed the discourse structure displayed in the material by relating the codes to each other according to their function as moments and nodal points (cf. section 1, aim 1). This reconstruction of structure allowed us to grasp the internal logics (Howarth & Torfing, 2004) of the material and the therein contained messages about the relationship between experts and laypeople. These could then be related to concepts and ideas from critical mathematics education relayed in section 2 (cf. section 1, aim 2).

1. Results & Discussion[[13]](#footnote-13)

Disclaimer: This contribution does not seek to make any judgements about people or institutions who were involved in the production of the media pieces we analysed. We furthermore distance ourselves from accusing anyone to have consciously intended the communication of the ideas we reconstructed in our analysis. We also do not believe that any of the media pieces analyzed is in any way ‘harmful’ (e.g. to society): they simply grant an insight into the discursive formation of the expert-citizen-relationship. We do, however, purport that discourses such as the ones analysed contribute to shaping the space of possibilities of ‘thinkable’ expert-citizen-relations.

### 4.1 Quarks

Adressee: The viewers of Quarks are assumed to be interested laypeople.

Short summary: Starting out from the initial question “How will the Pandemic continue?”, which is rephrased several times throughout the video and keeps the focus on the temporal progression of the crisis, the video guides the viewers through the modelling of several possible progression scenarios of the Corona-pandemic: “doing nothing” (02:52), “flatten the curve” (04:38), “stop the curve” (05:55), “spread in waves” (07:35). The explanations of each scenario use mostly everyday language and rely heavily on the visualization of the number of infected over time (represented as a yellow curve which has a different shape in each scenario) relative to the capacity of the health care system. Very few mathematical terms and scarcely any numbers are mentioned.

Important nodal points we identified are: *Corona virus pandemic*, *the curve, time*; important moments are: *people die*, *chain reaction*, *(mathematical) models*.

Detailed description and analysis: At 00:59, the video first establishes the information that the pandemic will only be over if 60-70% of people have become immune to the virus and then introduces the idea of a *chain reaction* as visual representation of the mathematical concept of exponential growth. The chain reaction, in turn, explains properties of the curve (Quarks B: “because of the chain reaction”). Immunity presents a solution to the pandemic, but at the same time opens up a new problem: „So we need immune people. The question now is, how do we make so many people immune?[[14]](#footnote-14)“ (Quarks, 2020; 02:11-02:17). This task of “making people immune” is said to be complicated by the danger of overburdening the health care system, which would result in casualties (*people die*). This is illustrated in the first progression scenario “doing nothing”: Looking at the graphical representation of this danger in Quarks B, time is represented as x-Axis, while *people die* is visualized in the surpassing of the dashed line (representing the “capacity of the health care system in Germany[[15]](#footnote-15)”) by *the* (yellow) *curve* (“number of infected[[16]](#footnote-16)”). Quarks C then defines the first variable of moral significance – human casualties – by framing the massive surpassing of the intensive care capacities and resulting deaths as an inconceivable horror scenario. In connection with other scenarios Quarks further mentions the negative impact of Corona measures on the population as morally relevant complication (secondary to casualties).

In the course of the video, the significance of *time* and *the curve* is construed differently for the two groups of scientists (experts) and viewers (laypeople):

For the viewer, *time* signifies the duration of the pandemic. A long duration is negatively connotated through the link to an equally longer duration of measures which negatively impact the economy and the psychological well-being of the population. For the scientists, *time* impacts decisively on the fulfillment of their role as engineers of solutions to the crisis (Quarks F): the more *time* the better.

*The curve* from Quarks B is a materialization in mathematical terms of the abstract issue of the development of the pandemic, which serves to make the situation more tangible for the viewer. It acts as point of contact between experts and laypeople as it constitutes shared knowledge and serves as communication device. The viewer, as recipient of an explanation of the situation, is expected to understand the reasons for and to be complicit in the implementation of Corona measures, but is not privy to expert knowledge about *the curve* (Quarks D). The realms of expert and layperson remain separated, as Quarks uses mathematics only to the extent necessary to give an explanation comprehensible for laypeople. On the scientists’ side, Quarks D construes *the curve* as the object experts manipulate in order to manipulate the development itself. Reality and the mathematical model become virtually indistinguishable as targets of experts’ activities (cf. materialization). Corona measures present a means for manipulating *the curve*: “switched-on” measures create more *time* for experts to work on solutions through a flattening of *the curve* (Quarks B, E & F). The measures taken are not presented as political decisions but as binary variables within a calculation (Quarks E) (cf. technicization of politics). The Corona-virus spread is presented as a (complex) technical problem, in which experts are expected to overcome technical uncertainties and gain control over the situation (Quarks F).

This technicization of politics results partly from the way Quarks links the *Corona virus pandemic* to citizenship: The pandemic is introduced as an event that concerns everyone – every citizen of Germany and the world, whether they are experts or laypeople (Quarks A). Experts and viewers (laypeople) are indeed two of only three relevant groups of people mentioned in the video. The only other category of people is the Quarks team themselves, who call themselves “science journalists” (Quarks, 2020; 00:12). There is no mention of politicians or nation states. Establishing control over the *Corona virus pandemic* is framed as community endeavor in which all citizens work together to achieve the best possible outcome for all. This project underlies a division of labor: Power over the curve (i.e. mathematics and science) clearly remains asymmetrically distributed and lies with the expert while the laypeople are expected to cooperate with experts by buying them time to do their job (Quarks F). Power over mathematics does, however, not imply power over citizens. The successful control of the progression of the pandemic relies on *informed consent*, obliging experts (or, in their stead, science journalists) to convince citizens through explanations of the need for a joint effort in implementing measures in society. It is unclear, however, what other choices of action a layperson, who wants to be a responsible citizen, has apart from trusting experts and aligning with their recommendations.

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| Quarks A(Quarks, 2020; 00:35) | We are experiencing an unprecedented situation that affects all people in the entire world.[[17]](#footnote-17)  |
| Quarks B (Quarks, 2020;02:52) |  |
| If nothing was done now to stop the spread of the disease, this is what would happen. The number of infected people would increase extremely strongly and rapidly because of the chain reaction. After a short time, the curve would also fall sharply again, because more and more people are immune and the virus finds it increasingly difficult to find non-immune people. The pandemic will be at an end. [[18]](#footnote-18) |
| Quarks C(Quarks, 2020; 03:39) | If we do nothing, the curve rises faster and faster and faster. Actually, one doesn't even want to imagine this... [pauses to emphasize][[19]](#footnote-19) |
| Quarks D(Quarks, 2020;05:07) | The curve must therefore not be too flat, but rather such that it scratches at its highest point at the capacity limit of our health care system. Scientists are now saying that it is almost impossible to achieve such a curve because it is extremely difficult to control […] If you make a mistake, the curve could rise again extremely quickly and go through the roof.[[20]](#footnote-20)  |
| Quarks E(Quarks, 2020;08:06) | So you would have to turn the measures back on. So schools closed, businesses closed, social distancing. Back and forth, turn measures on and turn measures off.The capacity limit of intensive care beds would not be exceeded, but only just reached. [[21]](#footnote-21) |
| Quarks F(Quarks, 2020;09:14) | All the measures we take now only buy us time in the end. But time, which scientists and researchers now urgently need, for the development of a vaccine and for medicines against the disease. Faster and better tests would also help […]. [[22]](#footnote-22) |

Table 2: Citations A to F from Quarks (2020).

### 4.2 RKI press conference

Adressee: The RKI as research institute is an established expert in the field of science; the viewer is conceived as layperson. At the same time, the RKI is a governmental institution and therefore also addresses the viewers in their role as German citizens.

Central nodal points we identified in this material are *numbers* and *RKI*; *estimates* and *officially reported numbers* are important moments.

Detailed description and analysis: The press conference starts with a situation report. This report starts and ends with the statements RKI A and RKI B respectively. In the course of the report, tables are read out in rather uniformly structured sentences that announce for different country groups the current number of Corona cases, the increase of cases compared to the day before, and the global percentage of deceased. The audience is flooded with *numbers*. Like a mantra, the speaker repeats that numbers are increasing (e.g. ZDFheute Nachrichten, 2020: 4:20 “As expected, the number [of cases in Germany] increases”[[23]](#footnote-23)) and concludes from the data that “the number of reported cases continues to be high” and that “the number of cases rises” (ZDFheute Nachrichten, 2020: 7:56)[[24]](#footnote-24). However, no visual support or additional elaborations on the context are given, which makes it difficult to follow the report or to form an impression of the general situation.

The report establishes two different kinds of *numbers*: The *officially reported numbers* (which are compiled in the institution of *RKI*) and *estimates[[25]](#footnote-25)*. *Officially reported numbers* are said to be more exact than *estimates*, but take longer to gather (RKI B). The concept of *officially reported numbers*, which is mentioned 14 times (with minor variations in wording), and the accuracy of these numbers, evoked also by the frequent mention of the exact time of the last update of data sets (6 times), maintain importance throughout the report. RKI C highlights the informative value of the *officially reported numbers* which stems from their connection to additional epidemiological information. As the RKI does not report this additional information, however, this statement devalues not just alternative sources of information, but the “plain numbers” (RKI C) relayed in their own situation report.

With regard to the “assessment of the situation” that is announced in RKI A we can conclude the following: the information given in the RKI’s situation report is by itself of low informational value and does not help citizens to form an opinion on the situation. The RKI does not give an evaluation of the situation either, apart from instilling vague worry by repeatedly stating that “numbers are rising”. However, without a reference for comparison or other context information, it is not possible to judge if 10.000 cases are “a lot” in a given scenario, or not. Paradoxically, the audience of the RKI press conference is simultaneously informed and not informed. We name this phenomenon *de|information*.

Regardless of this, the RKI asserts their numbers’ relevance: in RKI D, the question of how numbers come to the RKI and why the official numbers are so important is answered by emphasizing the hard work of the responsible employees, which is simultaneously linked to descriptions of legally prescribed counting and reporting procedures. The intertwining of people with bureaucratic procedures results in a personalization of criticism. Criticism of bureaucratic procedures is delegitimized as it now automatically implies an attack on the hard-working employees of the RKI.

The displayed relation between experts / the government (RKI) and laypeople / citizens (viewer) can be pointedly characterized as *de|informed subordination*. Mathematics is wielded by the expert in the form of numbers, which materialize the extent of the crisis but are at the same time so disconnected from the informational context as to thwart any hope for citizens of gaining a comprehending view of the situation. The expert’s tasks of providing transparency is formally fulfilled, critical questioning of the provided information by citizens is unwelcome. “*Officially reported numbers*” which are imbued with an aura of absolute certainty and high informational value – despite the fact that this information is not made accessible – can only be obtained through relentless efforts of the untiring workers of the RKI. The RKI’s communication projects into their numbers not just the ongoing crisis but the RKI’s very legitimacy as expert and governmental institution.

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| RKI A(ZDFheute Nachrichten, 2020; 00:21) | First, a brief assessment of the situation, i.e. the announcement of the numbers that have been officially reported [[26]](#footnote-26) |
| RKI B(ZDFheute Nachrichten, 2020; 06:08) | (…) this is the situation report, i.e. the plain facts, and we refer to officially reported numbers - not to estimates, but to officially reported numbers. This is similar to demanding an official election outcome: it [i.e. the official result] is more exact but takes longer to determine.[[27]](#footnote-27)  |
| RKI C(ZDFheute Nachrichten, 2020;03:16) | And I would like to stress again: this is the situation based on officially reported numbers. Not based on estimates or projections, but on officially reported numbers. These reported numbers do not only contain the plain numbers, but also epidemiological data on the cases, which are of course very important[[28]](#footnote-28)  |

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| RKI D(ZDFheute Nachrichten, 2020; 06:39) | I want to explain to you again how these numbers come to us and why we place importance on these officially reported numbers. If the local health authority is informed of a new case, this case must be transmitted no later than the next working day [...]. There is a legal requirement for this, [...] Many health authorities also transmit at the weekend, but not all of them, of course. Not everyone will, like the 150 or so employees in the Robert Koch Institute, who have been working in two shifts 7 days a week for 8 weeks, not everyone will do that [...].*[[29]](#footnote-29)* |

Table 3: Citations A to D from RKI (2020).

### 4.3 MaiLab

Adressee: The implied audience of this video are well-informed, mathematically literate citizens.

Short summary: The premise of the video is a lack of information (on the side of the viewer) about the foreseeable duration of the Corona crisis and its measures(MaiLab A). The aim of the video is to arrive at an estimate for the duration of the crisis and measures so that the viewers can arrange themselves early in time with the predicted course of events. To this end, the presenter walks the viewer through a mathematical modelling activity in the course of which the concept of the reproduction number (MaiLab B) and further assumptions and variables are introduced and explained. The use of mathematics is heavily normalized: techniques such as the interpretation of graphs or the use of tools to calculate graphs and values are presented as being quickly and easily applicable.

As nodal points of this material we identified: *duration of Corona crisis/measures*, *reproduction number* and *discovery through calculation*. Moments are for example *herd immunity*, *strategies of pandemic control*, *mathematical modelling*, *concrete numbers*.

Detailed description: The introduction of the video quickly declares the end of the Corona pandemic to be reached with herd immunity, i.e. immunity of 60-70% of the population.[[30]](#footnote-30) The speaker then expresses her dissatisfaction and disappointment with the fact that German media has not provided her with information about the pressing question of how long the crisis and related measures will likely persist, announces that she intends to fill this informational gap and warns the viewer that they will look at numbers that they might not really want to see (MaiLab A).

After this introduction, the speaker reiterates her point about German media coverage of the Corona crisis lamenting that there is no discussion about the expected duration of the pandemic even though this information is available. She then proceeds to introduce the viewer to “some necessary basics of pandemic control” (MaiLab, 2020: 2:26)[[31]](#footnote-31) (“necessary” to understand the subsequent elaborations): she introduces aims and strategies of phase 1 (“containment”) and phase 2 (“mitigation”) of pandemic control, linking the hashtag “flatten the curve” to phase 2. She then introduces the surpassing of the capacity of the health care system as scenario of utmost moral importance: this scenario “must not happen” (MaiLab, 2020: 4:12)[[32]](#footnote-32).[[33]](#footnote-33)

After this, the *reproduction number* (*R0*) is introduced. Its meaning is established by giving a definition of the general concept, by relating it to Corona measures which are said to aim at lowering the reproduction number and by explaining the signification of concrete reproduction numbers through the use of examples and graphical illustrations of possible pandemic progressions (e.g. MaiLab C). In contrast to Quarks, MaiLab uses the occasion to make some general comments on mathematical modelling and on the use and limitations of mathematical models (e.g. MaiLab D). The speaker then continues to introduce parameters to be used in the ensuing modelling process (total number of beds in critical care units in Germany; assumptions about how many infected people will need such a bed and for how long; etc.). The numerical values of these parameters are taken from presumably credible sources and the results of each model are calculated with the help of a preprogrammed calculation software the speaker found in a scientific report (i.e. the speaker does not perform all calculations herself but takes results from experts). The results of the modelling activity are these:

* The speaker links the various modelled scenarios back to the pandemic control strategies that were introduced in the beginning and uses them to explain why the strategy “flatten the curve”, i.e. mitigation, will only lead back to phase 1 and the application of strategies of containment – in other words: they will not end the pandemic.
* The speaker explains why she thinks that a better description of the current strategy is “stop the curve”, not “flatten the curve”.
* The pandemic will most likely persist for 1 to 2 years.

Other noteworthy points the video makes:

* To corroborate the results, the speaker mentions that she had an off-the-record conversation with an expert in order to verify the correctness of her reasoning. She gives the expert’s name and shows a brief shot of the videochat with him.
* In the further course of the video, the speaker presents various arguments (that became available with the background knowledge so far explained in the video) to justify the Corona measures currently in place, and emanates an understanding and accepting attitude towards the strategies pursued by the German government.

Analysis:

MaiLab provides an example in which mathematics and scientific knowledge are employed to pursue one’s personal agenda. By consulting expert knowledge from scientific sources, combining different theoretical elements and understanding experts’ mathematical calculations, well-informed citizens can find answers to questions that cannot be found elsewhere. Specifically, they can emancipate themselves from mass media and decrease their dependency on the selection of information discussed there. Mathematical modelling in particular is presented as a tool for the well-informed citizen to come to her or his own conclusions. In the given case, the activity of uncovering new information aims to increase one’s own functionality (e.g. by helping to decide whether or not to buy office equipment in preparation for the expected long period of home office) in a situation that is not considered alterable itself (i.e. scientific facts about the virus and the pandemic are not put to question; government measures are considered appropriate). In other words: the displayed engagement with the situation is not ‘critical’ in a narrow sense. However, the potential for a critical employment of researched information is not negated. The contribution of mathematics within this discourse can be labelled *discovery through calculation*.

The relationship construed in MaiLab between the implied viewer and experts lacks definite boundaries in the form of unsurmountable knowledge gaps. Experts are similar to teachers: they can be contacted and asked to check one’s results and interpretations (MaiLab E). They are granted authority over determining the correctness of citizens’ work (whose role is portrayed similar to that of students) and are expected to give feedback and explanations in an understandable manner. Experts also assist well-informed citizens in their endeavours of mathematical inquiry: in the MaiLab video an expert-made digital modelling tool is used to make calculations easier (MaiLab D). However, the mathematics underlying this particular program are neither questioned nor explained, which brings to mind the phenomenon of de|mathematization, specifically the machinery-commodity duality of devices. Overall, experts and well-informed citizens are construed as group of cooperating allies.

For the MaiLab video we have used the term “well-informed citizens”, not “laypeople”, to designate its intended audience. This is because the heavy normalization of scientific and mathematical inquiry evokes a split of the group of laypeople and an exclusion of the not-so-well-informed and not-so-mathematically-literate citizens, whose abilities or situational aspects (e.g. time-resources) stand in contrast to the pronounced normality of using mathematics, reading scientific reports and conversing with scientists in the video (cf. formatting power of mathematics). Although experts are, in principle, willing to collaborate with laypeople, the group of laypeople falls apart into the mathematically adept “well-informed citizens” addressed by the video and the “not-so-well-informed” citizens, who might even be alienated by the pronounced normality of mathematical and scientific inquiry.

Lastly, we take a look at the division of labour between experts and politicians as it is (implicitly) framed in the MaiLab video: experts are assumed to act as advisors for politicians who decide about measures to mitigate the impact of the virus. This labour distribution is accepted without discussion and may ground in the truth that is thought to lie in mathematics and science (cf. ideology of certainty, technicization of politics).

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| MaiLab A (MaiLab, 2020; 01:26) | So how long do we have to hold on for? At the moment, the main answers are: "It is still too early to say," [...] There are a few things we should talk about in detail right now, and also look at numbers that you might not want to see. […] I think there is not enough discussion about [this].[[34]](#footnote-34) |
| MaiLab B (MaiLab, 2020; 04:29) | Unfortunately [Pause] this expectation is unrealistic fantasy. We understand why this is so when we look at concrete numbers. Let's start with a central quantity: The reproduction number.[[35]](#footnote-35) |
| MaiLab C(MaiLab, 2020; 5:24) | y-axis: number of infectious personsx-axis: time (days) |
| MaiLab D (MaiLab, 2020; 05:24) | Graphically speaking, the lower the reproduction number, the flatter the curve. How flat is flat enough? This question is answered in the statement of the German Society for Epidemiology on the spread of the new Coronavirus. Here you can find models with different scenarios. These models are not predictions, mind you. […]. But: Models can calculate various possible scenarios, within which the future course of events could range. [[36]](#footnote-36) |
| MaiLab E (MaiLab, 2020; 10:45) | I have also spoken with Prof. Rafael Mikolajczyk, who co-authored this report, to make sure that we did not misunderstand basic information. Thank you, by the way, for the insightful off-the-record conversation. But yes, the results cannot be interpreted differently.[[37]](#footnote-37) |

Table 4: Citations A to E from MaiLab (2020).

### 4.4 Tagesschau

Adressee: The viewers of Tagesschau are German citizens, who are also laypeople.

The nodal points of this report are: *evaluation of Corona numbers* and *(Corona) tests*. Moments are: *experts*, *production of numbers* and *use of mathematics*.

Detailed description and analysis: The analyzed section of the news report is titled “Corona-pandemic: crisis peak yet to come, government says”[[38]](#footnote-38) (00:22–03:53). The main topic of this segment is “Corona numbers” (Tagesschau A) and their interpretation.

Firstly, the report differentiates between correct and incorrect usage of mathematics. Several examples of incorrect usage are provided, which all involve very basic mathematical techniques such as comparing values from tables, calculating a fraction or interpreting the magnitude of a number. Experts are cited condemning the incorrect application of these techniques[[39]](#footnote-39) (Tagesschau C) and warning against the (not further specified) dangers of misinterpreting Corona numbers on the basis of such incorrect calculations (Tagesschau A, C).

Secondly, the quality of Corona numbers can be distinguished on the basis of their production: There are meaningful and relevant numbers determined by respectable experts through thorough testing. And there are incorrect or meaningless numbers either created by potentially dishonest governments (North Korea is named as example) or by media outlets and unwitting citizens through a false application of mathematics.

In the Tagesschau video, the process of providing information is intertwined with a devaluation of laypeople’s ability to make sense of the numbers they are given. Even media outlets are accused of being unable to do correct calculations; their ability to inform citizens about the current state of affairs is thereby called into question. Fear of an incorrect employment of mathematical skills and of incorrect interpretations of Corona numbers, in extrapolation: fear of mathematics, is used to construe the citizen in a state of total dependency on expert knowledge and judgement. At the same time, the citizen is completely disconnected from the sphere of experts, as citizens have neither the skills to interpret the numbers experts provide nor do they have access to reliable secondary sources of information, as media outlets are equally incompetent. The citizen’s only apparent path of action is to blindly trust in the experts’ experience and judgement that reaches them only in the form of expert-informed political decisions (cf. technicization of politics). This relationship between experts and citizens/laypeople appears to be the same as in the RKI communication: *de|informed subordination*.

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| Tagesschau A (Tagesschau, 2020; 0:56) | Walks only for two, jogging with distance, the weekend in Germany. Always present, the latest Corona numbers: “(…) the infection rate is currently rising to more than 91,000, also a consequence of the up to 500,000 tests per week. Experts warn against misinterpreting [literally: evaluating incorrectly] the rising numbers.[[40]](#footnote-40) |
| Tagesschau B (Tagesschau, 2020; 01:58) | But, according to experts, comparisons between countries are often not very meaningful. One should not compare these numbers, especially not in a kind of ranking table, because the countries are of very different sizes and they have very different test capacities. [...][[41]](#footnote-41) |
| Tagesschau C (Tagesschau, 2020; 02:28) | The typical way of calculation, and this is plainly wrong, is to look at the number of deaths at the current point in time divided by the number of known cases. And one has to be aware that the numerator as well as the denominator of this calculation have big uncertainties and problems.[[42]](#footnote-42) |

Table 5: Citations A to C from Tagesschau (2020).

### Comparison of the four videos

We first compare the **use of mathematics** between MaiLab, Quarks and RKI/Tagesschau[[43]](#footnote-43): MaiLab and RKI/Tagesschau focus on “concrete numbers”. In contrasts to the RKI/Tagesschau, however, MaiLab’s communication is not limited to numbers as the mathematical elements of preference. The MaiLab contribution provides the context information (from science and mathematics) necessary to make sense of the numbers that ultimately answer the video’s questions. Quarks, like RKI/Tagesschau, limit themselves to certain mathematical aspects, but, unlike RKI/Tagesschau, focus only on graphical representations, excluding numbers completely from their discussion. Together with the numbers, however, they also exclude the possibility of active participation through mathematical calculation. The viewer of Quarks is thereby construed as passive. Tagesschau takes the exclusion of active participation of citizens in the discourse about Corona a step further: they advise not to do any calculations (with the RKI’s and other such institutions’ numbers). Meanwhile, MaiLab actively employs and encourages calculations to further a personal agenda.

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|  | **Relationship** **experts – laypeople**  | **Citizens’ sphere of influence in connection with mathematics** | **Role of mathematics** |
| **Quarks** | Laypeople are expected to understand simplified explanations of expert knowledge and to cooperate with experts by heeding their recommendations (*informed consent*). They don’t communicate with experts directly, but with science journalists.Experts themselves are intangible and anonymous.  | Citizens cannot really use the mathematics actively as no numbers are presented and calculations are therefore impossible. The citizens are basically recipients of information that they are expected to understand (one-sided communication).  | Mathematics is used to make information better understandable (communication device). The mathematics used is reduced to graphical illustrations (qualitative mathematics), which constitute shared knowledge of experts and laypeople. Mathematical objects are targets of experts’ work. |
| **RKI** | Experts work for laypeople and their work needs to be valued. The expert RKI has the duty to inform the public about the Corona crisis, but does so only formally. Despite this, laypeople’s criticism is unwelcome. (*de|informed subordination*) | As the numbers relayed by the RKI are devoid of any real meaning because of their complete disconnectedness to any context information, they do not give any power to the citizen even if they were to start calculating. The numbers by themselves are useless.  | Mathematics is used to give an impression of preciseness and to incite worry. The mathematics used is reduced to numbers (quantification), without any contextualization (or meaning). Numbers are a result of experts’ work and can be of different quality.  |
| **MaiLab** | Experts are like schoolteachers: available for explanations but more experienced than the students. That is why they have “the last word”. Experts are “in reach” of the informed citizens (in terms of understanding but also communication). (*cooperating allies*)The group of laypeople, however, is split into the well-informed and the not-so-well-informed, who do not have this privileged access to experts.  | Well-informed citizens can emancipate themselves from mass media and use mathematical modelling to generate their own original information.  | Mathematics is used qualitatively and quantitatively, functioning as tool for emancipation (*discovery through calculation*), but also has excluding properties. Mathematics is a freely available tool.  |
| **Tagesschau** | Citizens are disconnected from the sphere of experts through a lack of knowledge and skills and a lack of access to information. Experts’ work is valued and legitimized through subtle devices of fearmongering. (*de|informed subordination*) | The citizens’ sphere of influence is practically non-existent, as they do not have adequate mathematical abilities and knowledge. They have to trust politicians and experts to take the right decisions.  | Using mathematics and making wrong calculations is presented as a danger. Science and the use of mathematics are generally mystified.  |

Table 6: Overview of findings relating to the second aim of our analysis (cf. section 1).

The **roles of citizens** construed in the materials cover a range from passive (being informed) to active (discovering/calculation) usages of mathematics. The ‘passive’ option is that of subordinating oneself and staying alert while the ‘active’ option includes using mathematics to ‘adapt’ most effectively to the measures taken. However, the way both the passive and the active positions are presented reminds us of what Kennelly & Llewellyn (2011) term *active compliance citizenship*[[44]](#footnote-44): in this discursive formation citizens are largely excluded from political decision-making processes. In our materials, only experts are presented as being knowledgeable enough to participate in discussions about measures.

## Discussion: Looking forward

Like Jablonka & Bergsten (2021), we could not find any evidence in our (limited) data material that sedimented discourses or taken-for-granted truths about mathematics – in particular the use of mathematics to justify political decisions – were at stake. We were, however, able to outline, in this case study, how argumentative patterns described in the mathematics education literature (cf. section 2) appear in instances of early Corona reporting by the German public broadcasting service. It was less the occurrence of said patterns, however, that was remarkable than the observation that variations in their interplay allowed for quite different expert-layperson-relationships (section 4.5). In other words, all materials considered in this paper constitute 'citizens' in relation to 'experts' with the help of mathematics, but in very different ways. These different takes on citizenship and the role of mathematics stand in contrast to the simplicity of the ideal of the mathematically literate reflective citizen, who uses his or her mathematical skills to actively participate in social and political life (cf. OECD definition). This observation is decidedly not intended to carry judgmental undertones towards the producers of the media contributions but should motivate investigations into the conditions of possibility of the observed discourses and into their societal function(s).

Taking a look at *power relations* it becomes apparent that Fischer’s idealized model of political decision-making processes assumes asymmetrical power constellations (see section 2): When politicians consult experts in order to draw on their (scientific) expertise, experts can only advise politicians, but it is the function of politics to make and carry out the decisions. Citizens (ideally conceptualized as actively participating in the political process) stand in a similar relation to experts, as they are expected to base their reflected judgements on facts, in other words, on expert knowledge. Power is constituted in two different forms, *knowledge* and *decision-making*, and unequally distributed among the three groups of actors. Within this description, it might be easily presupposed who is an expert and who is a layperson. But it is not always clear, who has relevant expertise and how different forms of expertise are related to each other in political decision-making. In our examples, mathematics served to establish an expert-status (e.g. RKI). If we follow Biesta’s argument that the meaning of citizenship is not a positive, definable identity (section 2) and, as such, the duplet concept of expert|layperson is no fixed entity but their specific relationship is constituted in discourse, then the question of the communicative framing of these roles needs to be made a topic in education. Public media plays an important role in the organization of expert-laypeople communication at a large scale. Our findings suggest that reducing Fischer’s work to a didactic model of educating laypersons for expert-citizen communication cannot do justice to the complexities of political processes as a part of the broader social order. Such reduction to a didactic model bears the danger to reduce the role of mathematics to the provision of information/facts and deny its formative power in the constitution of the relationship. Instead expert-citizen communication should be seen as an institution that organizes life in modern societies. Following this perspective, our findings point to two interrelated basic dilemmas: (1) The division of labour and necessary specialisation in modern societies requires an organisation of shared responsibility. The degree of modern specialization demands a distinction between experts and laypersons, which in turn makes it necessary to deal with the tension between trust and critical scrutiny in communication. (2) In theory, representative democracy demands that individuals be informed in such depth, that they can make ‘informed decisions’. Kollosche & Meyerhöfer (2021) formulate the demand on compulsory mathematics education derived from this as follows:

“*Maturity and citizenship in a democracy require that laypersons are able to critically evaluate experts’ use of mathematics. Learning to critically reflect on the use of mathematics, including the acquisition of the mathematical knowledge and skills required to that end, has been repeatedly postulated as an indispensable goal of compulsory education in mathematics. However, it remained unclear in how far such reflection is possible, even for the well-educated layperson in mathematics*.” (p. 401)

This short quote already hints at doubts about the feasibility of this demand.

In Klafki's sense (2007), these two interrelated basic dilemmas can be regarded as an *epoche-typical key issue* (*epochaltypisches Schlüsselproblem*), that manifested in the mathematics-heavy crisis communication about COVID-19 in a particular manner. Epoche-typical key issues describe general challenges of coexistence and organizing life in a modern democratic society and are furthermore specific to the era people live in. Their elaboration is considered to be substantial for general education. Central for the educational endeavour is the collaborative elaboration and negotiation of these tricky, ambiguous, and not univocally solvable issues. Therefore, the educational task goes beyond the provision and transmission of stockpile knowledge. Of course, being knowledgeable, at least of the basics, is necessary for a democratic citizenship education. But it is not sufficient. Indicating possibilities of democratic access and participation and thus also identifying areas of tension and obstacles in and for the democratic process[[45]](#footnote-45) are equally important tasks of (critical) citizenship education. Education cannot solve this epoche-typical key issue, but it can offer a space for collective confrontation with, examination of and discussion about it, thus making possible a joint handling of it. For this educational endeavor questions relating to the entanglement of mathematics in social relations need to be considered a legitimate part of mathematics education and be open for debate. Jablonka’s & Bergsten’s (2021) proposal to make strategies of using mathematics in political discourses visible to students could be a first step in this direction of fostering critical mathematical literacy.

To create a basis for such educational processes, we see it as a relevant task for mathematics education research to gain a better understanding of the entanglement of mathematics in political discourses and to find theoretical terms that aid the reflection of complexities instead of taking the ‘meaning of using’ mathematics for granted. As long as mathematical literacy is merely understood as an individual’s capacity of making use of mathematics and sole (mathematics-related) prerequisite of being a good citizen, mathematics is not only part of defining who is considered to be eligible to participate in a democratic process but also reduced to a device for granting access to the supposedly ‘democratic’ negotiation of political decisions. Possibilities for a democratic expert-layperson relationship that reflects the ‘meaning of using’ mathematics would be denied.

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1. Nodal points themselves are "empty", their meaning only becomes apparent through the discourse arrangement (relationship to the other signs in the discourse). In other discourses the sign can have a completely different meaning. [↑](#footnote-ref-1)
2. This view finds support in political documents, such as educational standards or the OECD’s description of the general aims of mathematics education. [↑](#footnote-ref-2)
3. The perspective of the question changes in these ways: ‘citizenship’ is converted from a fixed normative idea(l) into an external state of affairs which is construed in discourses; we do not ask “what mathematics should the individual know to be able to fulfill some ideal role” but “what is the role of mathematics in creating certain roles for individuals in concrete discourses”. [↑](#footnote-ref-3)
4. This source is a short English summary of a book published in German. Our understanding derives from the extended German version, but to facilitate accessibility for international readers, we will refer to the English version in this article. [↑](#footnote-ref-4)
5. Keitel (1998) also gives examples for the reverse process of how demathematisation reinforces mathematization. [↑](#footnote-ref-5)
6. The German public broadcasting service is obliged by law to be independent of any party interests and is financed via a general fee and therefore not dependent on financing by lobby groups or businesses. [↑](#footnote-ref-6)
7. “RKI” stands for *Robert Koch Institute. “*The Robert Koch Institute (RKI) is Germany's national Public Health Institute. It is the central institution of the Federal Government in the field of surveillance, control and prevention of diseases” (https://www.bundesgesundheitsministerium.de/english-version/ministry/authorities-within-the-remit/robert-koch-institute-rki.html) (see also: <https://www.rki.de/EN/Content/Institute/Profile/profile_node_en.html>). [↑](#footnote-ref-7)
8. All videos are published via YouTube and still acessible to all readers (last checked: 17.02.2023). [↑](#footnote-ref-8)
9. Of the publication on Youtube. [↑](#footnote-ref-9)
10. The videos were all accessed on the given dates between 19:00 and 00:00. [↑](#footnote-ref-10)
11. YouTube's *trending* is a ranking list that shows the most popular videos in the user's country at a given point in time. The algorithm considers parameters such as view count, growth rate of view count, age of video, etc. [↑](#footnote-ref-11)
12. Many more people would have seen this program on TV, the Youtube viewcount is therefore misleading. Cf.: <https://de.statista.com/statistik/daten/studie/182978/umfrage/reichweite-der-tagesschau-seit-1992/> [↑](#footnote-ref-12)
13. In the early German COVID-19 discourse, COVID-19 is referred to as ‘Corona’. In this section (section 4), we will therefore also use this term interchangeably with COVID-19. [↑](#footnote-ref-13)
14. Wir brauchen also Immune. Die Frage ist jetzt, wie machen wir so viele Menschen immun? [↑](#footnote-ref-14)
15. Kapazität des Gesundheitssystems in Deutschland [↑](#footnote-ref-15)
16. Anzahl Infizierter [↑](#footnote-ref-16)
17. Wir erleben gerade eine noch nie dagewesene Situation, die alle Menschen auf der ganzen Welt betrifft. [↑](#footnote-ref-17)
18. Würde man jetzt gar nichts gegen die Ausbreitung der Krankheit unternehmen, dann würde das hier passieren. Die Zahl der Infizierten würde extrem stark und schnell ansteigen, wegen der Kettenreaktion. Nach kurzer Zeit würde die Kurve auch wieder stark fallen, weil immer mehr immun sind und es das Virus immer schwerer hat, nicht Immune zu finden. Die Pandemie wäre zu Ende [↑](#footnote-ref-18)
19. Tun wir nichts, steigt die Kurve immer schneller und schneller. Eigentlich will man sich das gar nicht vorstellen... [betonende Pause] [↑](#footnote-ref-19)
20. Die Kurve darf also nicht zu flach sein, sondern so, dass sie auf ihrem höchsten Punkt an der Kapazitätengrenze unseres Gesundheitssystems kratzt. Die Wissenschaftler sagen inzwischen, dass es fast unmöglich ist, eine solche Kurve hinzubekommen Denn den Anstieg der Kurve zu steuern, ist extrem schwierig. Jede Maßnahme, die man ergreift, zeigt erst in ein oder zwei Wochen Ergebnisse. Macht man dabei einen Fehler, könnte die Kurve extrem schnell wieder ansteigen und durch die Decke gehen. [↑](#footnote-ref-20)
21. Also müsste man dann die Maßnahmen wieder einschalten. Also Schulen wieder zu, Geschäfte wieder zu, soziale Distanzierung. Immer hin und her, Maßnahmen einschalten und Maßnahmen ausschalten. Die Kapazitätsgrenze der Intensivbetten würde dann nicht überschritten, sondern immer nur knapp erreicht. [↑](#footnote-ref-21)
22. Alle Maßnahmen, die wir jetzt ergreifen, kaufen uns am Ende nur Zeit. Zeit, die Wissenschaftler und Forscher jetzt aber auch dringend brauchen, für die Entwicklung eines Impfstoffs und für Medikamente gegen die Krankheit. Auch schnellere und bessere Tests würden helfen […]. [↑](#footnote-ref-22)
23. (…) wie erwartet nimmt diese Zahl zu (…) [↑](#footnote-ref-23)
24. Sie sehen an unseren Meldedaten, dass weiter viele Fälle gemeldet werden. Die Fälle nehmen zu. [↑](#footnote-ref-24)
25. The estimates can be associated with the numbers provided by the Johns Hopkins University at the time, but this is not explicitly mentioned in our material. [↑](#footnote-ref-25)
26. Zunächst eine kurze Lageeinschätzung, d.h. die Vermeldung der Zahlen, die offiziell gemeldet wurden. [↑](#footnote-ref-26)
27. Das ist der Lagebericht, also die nüchternen Fakten und wir berufen uns auf offizielle Meldezahlen – nicht auf Hochrechnungen, sondern auf offizielle Meldezahlen. Das ist etwa so, als wenn Sie ein amtliches Ergebnis haben wollen: das ist eben genauer und dafür braucht es ein wenig länger. [↑](#footnote-ref-27)
28. Und ich möchte wieder betonen: das ist die Situation, die auf offiziellen Meldezahlen beruht. Nicht auf Schätzungen oder Hochrechnungen, sondern auf offiziellen Meldezahlen. Diese Meldezahlen beinhalten ja nicht nur die reinen Zahlen, sondern auch epidemiologische Daten zu den Fällen, die natürlich sehr wichtig sind. [↑](#footnote-ref-28)
29. Ich möchte nochmal Ihnen erklären, wie diese Zahlen zu uns kommen und warum wir auf diese amtlichen Zahlen Wert legen. Wenn das örtliche Gesundheitsamt über einen neuen Fall informiert wird, muss dieser Fall spätestens am nächsten Arbeitstag […] übermittelt werden. Dafür gibt es eine gesetzliche Vorschrift, […] Viele Gesundheitsämter übermitteln auch am Wochenende, aber natürlich nicht alle. Nicht jeder wird, wie die etwa 150 Mitarbeiter im Robert Koch Institut die seit 8 Wochen in zwei Schichten 7 Tage die Woche arbeiten, das wird nicht jeder tun […]. [↑](#footnote-ref-29)
30. „Solange wir keinen Impfstoff haben, ist die Pandemie erst vorbei, wenn sich 60-70% der Bevölkerung infiziert haben (…) [und] immun sind, dann haben wir nämlich ‚Herdenimmunität‘, (…)“ (MaiLab 2020: 0:34) [↑](#footnote-ref-30)
31. „Um das alles zu verstehen kurz vorweg ein paar Basics zu allgemeinen Epidemiemaßnahmen.“ (MaiLab 2020: 2:26) [↑](#footnote-ref-31)
32. „Das darf nicht passieren.“ (MaiLab 2020: 4:12) [↑](#footnote-ref-32)
33. Later in the video, effects of Corona measures on people are also mentioned as complication of secondary importance. [↑](#footnote-ref-33)
34. Wie lange müssen wir also noch durchhalten? Als Antwort hört man momentan vor allem: "Das ist noch zu früh zu sagen.", […] Über'n paar Dinge sollten wir jetzt schon ausführlich sprechen, und auch Zahlen anschauen, die man vielleicht nicht sehen möchte.

Ich mein, es ist ja auch richtig und wichtig im Nebel auf Sicht zu fahren. Aber wir wollen doch trotzdem ungefähr wissen, wie lang die Straße sein wird, oder? Und die Sache ist die: über die Länge der Straße wissen wir jetzt schon ziemlich gut Bescheid. Und bei all der Berichterstattung über die Corona-Krise ist genau das 'n Punkt, über den meiner Meinung nach zu wenig diskutiert wird. [↑](#footnote-ref-34)
35. Diese Vorstellung ist leider [Pause] realitätsferne Fantasie. Warum das so ist, verstehen wir, wenn wir uns konkrete Zahlen anschauen. Fangen wir an mit einer zentralen Größe: Die Reproduktionszahl [↑](#footnote-ref-35)
36. Grafisch gesprochen je kleiner die Reproduktionszahl, desto flacher die Kurve. Wie flach ist nun flach genug? Diese Frage wird beantwortet in der Stellungnahme der deutschen Gesellschaft für Epidemiologie zur Ausbreitung des neuen Coronavirus. Hier findet man Modellierungen mit verschiedenen Szenarien. Diese Modellierungen sind wohlgemerkt keine Voraussagen. […]. Aber: Modellierungen können verschiedene denkbare Szenarien durchrechnen, in deren Rahmen sich der zukünftige Verlauf bewegen könnte. [↑](#footnote-ref-36)
37. Ich habe auch mit Professor Rafael Mikolajczyk geredet, der diese Stellungnahme mitverfasst hat, um mich zu versichern, dass wir nicht etwas Grundlegendes missverstanden haben. Vielen Dank an dieser Stelle für das aufschlussreiche Hintergrundgespräch. Aber ja, die Ergebnisse sind nicht anders zu interpretieren. [↑](#footnote-ref-37)
38. Corona-Pandemie: Krisenhöhepunkt steht laut Regierung noch bevor [↑](#footnote-ref-38)
39. This criticism is formulated very generally, but German mass media such as newspapers appear as (exemplary) targets: images of newspaper pages are shown but no specific sources are mentioned. [↑](#footnote-ref-39)
40. Spaziergänge nur zu zweit, Joggen mit Distanz, das Wochenende in Deutschland. Dabei immer präsent, die neuesten Corona-Zahlen: die Infiziertenrate steigt auf aktuell mehr als 91.000, auch eine Folge der bis zu 500.000 Tests pro Woche. Experten warnen davor, steigende Zahlen falsch zu bewerten. [↑](#footnote-ref-40)
41. Aber, so Experten, Ländervergleiche sind oft wenig aussagekräftig. „Man sollte diese Zahlen nicht, schon gar nicht in einer Art Rankingtabelle, vergleichen, denn die Länder sind sehr unterschiedlich groß und sie haben sehr unterschiedliche Testkapazitäten. (…)“. [↑](#footnote-ref-41)
42. „Wie typischerweise berechnet wird, und das ist im Grunde einfach nur falsch, ist, die Zahl der Toten zum Zeitpunkt jetzt geteilt durch die Zahl der bestätigten Fälle sich anzuschauen. Und man muss sich bewusst sein, dass sowohl der Zähler als auch der Nenner von dieser Rechnung große Unsicherheiten und Probleme haben.“ [↑](#footnote-ref-42)
43. We lump RKI and Tagesschau together as the use of mathematics in their communications is very similar. [↑](#footnote-ref-43)
44. Within this constellation an emancipatory potential of mathematics can be doubted. [↑](#footnote-ref-44)
45. As Fischer details in his arguments about mathematics in implicit and explicit culture, mathematics is entangled on both sides. [↑](#footnote-ref-45)