# How Users Review Frequently Used Apps and Videos Containing Mathematics

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*Hardly any other topic is currently as much the focus of social and scientific interest as the use of digital media in educational contexts. In this project, we examine the user perspective. We will explore which findings can be generated from freely accessible user reviews within the app stores and on YouTube regarding users' personal backgrounds, the usage contexts, emotions and attitudes, as well as the subjectively perceived qualities and shortcomings of digital learning offerings. 1268 user reviews of frequently used apps and explanatory videos with content from primary and secondary school mathematics form the data basis of the article. The results indicate that the selected digital learning opportunities are predominantly evaluated positively by the users, whereby the perceived qualities mentioned are rather to be classified as surface features. Perceived shortcomings of the digital learning opportunities are mentioned rarely. Regardless of whether the content of the digital learning opportunities is curricularly located in the primary or secondary level, they are more likely to be used by learners from the secondary level. The users also state that they use the learning opportunities primarily for exam preparation as well as for learning and understanding mathematics. However, the latter two fields of uses seem less suitable from a subject didactic perspective.*

## 1. INTRODUCTION

Since the 1970s, digital tools and media have been an important part of mathematics teaching and learning. Since then, the available technology has constantly changed in shape and functionality. In the last decade especially, mathematical apps and learning videos have become a broadly used aid for learning mathematics. Looking at freely available reviews of apps and videos on the respective platforms provides an impressive overview of the euphoria most users seem to have when using such learning opportunities. To illustrate this, two exemplary reviews are displayed in Figure 1.

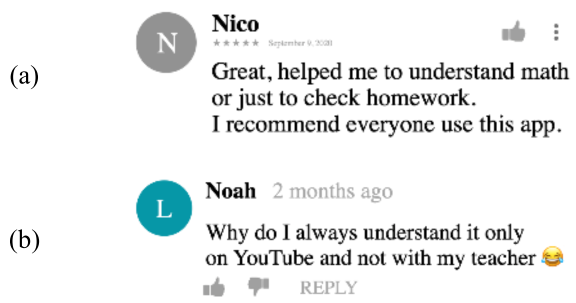


Figure 1. Selected reviews on a) the app Photomath and b) an explanatory video on YouTube (names changed, translated from German)

Even if not used in the classroom, such learning opportunities seem to be an important part of many students' everyday life. However, there is a lack of research systematically investigating how and why students use freely available apps and videos, especially when students are in out-of-class learning settings. With this research, we try to fill this gap. For this, we make use of freely available online reviews like the ones shown above.

We retrieved 1268 reviews for two apps and three learning videos on YouTube for the primary as well as the secondary level and qualitatively analyzed them to obtain an insight into usage contexts, fields of uses, and emotions and attitudes of the users as well as the subjectively perceived qualities and shortcomings of digital learning opportunities.

Before we outline our study in more detail, we will lay out the potential scene of usage more clearly and describe what is already known of mathematical apps and videos regarding learning mathematics.

## 2. THEORETICAL BACKGROUND

### 2.1 Setting The Scene

In modern pedagogy and didactics, learners are increasingly understood as architects of their own learning processes. This does not only apply to teaching scenarios that take place in the school. It is also reflected in learning phases in which learners are physically outside the school and, therefore, in an informal context. We do not intend to describe learning processes where students leave their classrooms to explore the outside world together with their teachers, but the situation when learners are not under instructional supervision and do or learn mathematics by themselves, in most cases probably at home. Although extrinsically driven by upcoming exams or given homework, these learning processes take place in a rather informal and often technology-supported setting.

Modern technology and foremost the internet offer a wide range of digital information and learning opportunities. In addition to classic web research, these include, above all, freely available mathematical resources online such as learning videos (especially on YouTube) or learning apps (Barzel, Ball & Klinger, 2019). This is reinforced by a massive increase in smartphone availability among young people and children in Western societies. As for Germany, 97 percent of 6- to 13-year-olds and 99 percent of 12- to 19-year-olds have access to modern mobile technology, such as smartphones or tablet computers (Feierabend et al., 2019; 2020).

With the availability of mobile devices from the mid-2000s onwards, this *learning on demand* seems to have become a lifestyle of the young generation (cf. McLoughlin & Lee, 2007): “Learners constantly seek information to address a problem at work, school, or to just satisfy a curiosity” (Dabbagh & Kitsantas, 2011, p. 4). However, there seems to be a lack of research on students’ learning when it is self-initiated and assessed in an out-of-classroom environment (Muir, 2014; Shuler, 2012).

To address this lack, we will outline the scene more clearly and describe it with terms already coined by previous literature. The scene described touches the triangle of *formal, non-formal,* and *informal* learning.

Those notions, though primarily coined regarding adult education, are relevant for the entire lifetime as they relate to the topic of lifelong learning. Although there is no unified definition of these notions, and their meaning even differs from country by country (Werquin, 2016), one can point out that *non-formal* and *informal* learning are, in a certain sense, opposed to *formal* learning. Whereas the latter describes intentional, strongly organized, and structured learning opportunities which are usually arranged by institutions, such as schools or universities, and lead to a formal qualification, *non-formal* and *informal* learning is less organized (Ainsworth & Eaton, 2010). Nevertheless, *non-formal* learning opportunities are typically organized in some way. The learning processes may or may not be intentional or arranged by an institution, even though there are no formal credits granted. *Informal* learning is neither organized nor guided by a rigid curriculum (Ainsworth & Eaton, 2010). While *non-formal* learning opportunities may aim at certain learning objectives, *informal* learning occurs spontaneously and is rather unplanned (Werquin, 2007).

From another perspective, our scene does not have to occur in a learner’s room or even at home at all. Since we focus on learning with apps and videos which essentially run on mobile devices, learning can principally happen anywhere. Thus, mobile learning plays an important role. Whereas the more classical notion of electronic or e-learning applies to an essentially stationary setting, “mobile learning refers to the use of mobile or wireless devices for the purpose of learning while on the move.” (Park, 2011, p. 79) In consequence, learning with mathematical apps and videos can happen at home, on the move, together with friends, or in an out-of-class situation in school, and eventually even in a formal and structured setting initiated by the teacher.

In that sense, our scene does not clearly fit into one of the mentioned categories. It unites aspects of non-formal and informal learning since it is probably not institutionally organized but aims at a certain self-imposed learning objective (like mastering a test or getting homework done). However, it is not strictly outside formal learning since the device’s mobility enables a variety of possible classroom applications. Furthermore, one can assume a strong dependence because even if the setting is informal or non-formal, the learner’s motivation will typically stem from the desire to master goals set by formal institutions and their curricula. In conclusion, our scene is set in a highly mobile learning setting within the triangle of formal, non-formal, and informal learning with a tendency to the more *non-formal* and *informal* learning opportunities.

In this paper, we focus on learning with market-leading – i.e., frequently installed or accessed – apps and videos as central components of learning with digital media in *non-formal* and/or *informal* settings. In the following two sections, we present key research findings on these digital learning opportunities.

### 2.2 Apps Containing Mathematics

With the advent of smartphone and tablet apps, ‘educational’ apps also found their way into the so-called app stores of the current duopolists Apple and Google. We assume that such apps are mostly used in an informal learning setting like the ones outlined above. Unfortunately, there is not a lot of research exploring such apps, so little is known of the students’ use of these resources and their effectiveness for learning mathematics (Highfield & Goodwin, 2013; Moyer-Packenham et al., 2015; Muir, 2014).

On the one hand, the variety of corresponding apps is obviously large, especially of apps concerning mathematical topics. Such apps are quite popular: The number of five-star-ratings and downloads suggests that a substantial group of users exists for them (Klinger, 2019; Klinger & Walter, 2020).

On the other hand, these apps are often of poor didactic quality (Larkin 2015) and foster procedural or declarative rather than conceptual understanding (Larkin & Milford, 2018; Namukasa et al., 2016; Muir, 2014). In addition, several analyses by Goodwin and Highfield (2013) found that about three quarters of the available apps can be assigned to the category ‘drill-and-practice’ and do not seem suitable for supporting mathematics learning. Krauthausen (2012, p. 49) even speaks of a “quality dilemma” in this context, while Guernsey and Levine (2013) characterize the current state of ‘educational’ apps as a “digital Wild West” (cf. Papadakis et al., 2020). The existing pool of apps containing mathematics does not seem suitable for comprehensively fostering the wide range of competencies expected in standards. Larkin (2013) shows in his analyses that 128 of the 143 apps examined focus on the *Number and Algebra* area of the Australian curriculum. Other content areas, however, are only rudimentarily addressed. In an ongoing survey of the apps currently on offer, Walter (in preparation) shows that apps containing mathematics (n=110) available in Germany focus primarily on *Numbers and Operations* while, at the same time, offering little in terms of fostering process-related competencies.

The goal of this paper is to explore this paradoxical situation of high usage on the one hand and low educational quality on the other. The challenge is to keep up with a fast moving market, since “[…] research on how these apps benefit children’s learning has not kept pace with the explosion of apps being created“ (Moyer-Packenham et al., 2015, p. 42f).

### 2.3 Videos Containing Mathematics

Like mathematical apps, online learning videos about mathematics (especially on YouTube) have become a substantial learning aid for many students. Wolf (2015) defines *explanatory videos* as "self-produced films that explain how to do something, or how something works, or in which abstract concepts are explained" (p. 123, translated). In contrast, videos in which an observable skill is shown in the sense of a documentation or a self-presentation without further didactic processing are called *performance videos*. In that sense, mathematical learning videos are mostly characterized as explanatory videos since it is unlikely to find videos seeing the protagonist just calculating without giving further instructional comments.

However, "explaining" is not a one-dimensional construct. It can be subdivided into different types of explanations: *Explain-How*, *Explain-What* and *Explain-Why* (Schmidt-Thieme, 2009):

- *Explain-How* includes explanations of actions and functions of all kinds.
- *Explain-What* deals with the negotiation of terms.
- *Explain-Why* deals particularly with explanations of connections.

Each of these three types of explanation has its benefit, which we will briefly sketch using the example of written subtraction. *Explain-How* is necessary to know how to perform the procedure without making unnecessary mistakes. *Explain-What* provides valuable declarative knowledge about mathematical objects, here, for example, what the written subtraction actually is. *Explain-Why*, on the other hand, is central to the understanding of why the procedure always works – regardless of the numbers subtracted. Accordingly, we maintain a balanced ratio of videos that take these different types of explanations into account.

Although there is – so far – no systematic mathematics-specific survey quantifying the number of available explanatory videos on popular video platforms, numerous researchers emphasize that videos of the "*Explain-How*" type seem to dominate, followed by the "*Explain-What*" type (e.g., Römer & Nührenbörger, 2018; Schöttler, 2020). Videos of the *Explain-Why* type, which can promote understanding in a special way and can be used to show why mathematical relationships exist, are extremely rare. Accordingly, there are relatively many videos that promote calculus and procedural aspects rather than understanding. Research conducted in non-mathematics studies confirms this thesis for other subject didactics as well. The videos analyzed are usually of an expository and monological nature (Lobato et al., 2019; Lee & Lehto, 2013) and are most likely consulted in examination situations (Cardoso et al., 2014). Such videos attract considerable attention among users while there is little scientific evidence on their use and effectiveness.

One can observe the same paradoxical situation as with apps containing mathematics: high usage contrasts with low educational quality. Moreover, as Kulgemeyer and Peters (2016) have found for physics-related videos, there is not even a relationship between user ratings (measured in the number of likes and views) and the theoretically determined "exploratory quality". This already suggests that users and scientists apply very different quality criteria.

The question of why this discrepancy exists is rather unexplored in subject didactics. It can be speculated that the available, frequently used videos fit the perceived needs of learners – such as a brief refresher of content or support in the correct application of mathematical procedures required in class. This study aims to contribute to an empirical basis to learn more about fields of use and reasons for using videos – and also apps.

## 3. DESIGN OF THE STUDY

### 3.1 Aim Of The Study And Research Question

To obtain an insight into the out-of-classroom world of mathematical learning apps and videos, our study aims at answering the following research question: *How, why and for what purpose are digital* learning *opportunities like apps and videos containing mathematics used in informal settings?*

To investigate this mainly private environment in an as unbiased manner as possible, we focus on user reviews in the app stores and on the YouTube platform. We would already like to point out that such an approach must be considered exploratory and should be validated in the last instance by further studies. We discuss this topic in section 5.2.

### 3.2 Reviews As Source Of Data

Freely available user reviews offer a powerful insight into an app's user experience (Khalid et al., 2015). To our knowledge, all previous studies using user reviews as data sources have applied quantitative methods and provided certain features of automatically analyzing an app's reviews. This mostly happens with an economic focus, so that these studies are not very helpful for our research.

However, our own preparatory work has already shown that reviews are a meaningful source of information in the case of mathematical learning apps (Klinger 2019). Such reviews, especially when analyzed qualitatively as here, offer a variety of insights covering all of the above-mentioned dimensions. As far as we know, this is the first time such data is used in the field of mathematics education research.

As described above, mathematical learning videos on YouTube are an important learning aid, too. Although user comments on YouTube videos have been used as a data source in the context of scientific studies (e.g., Poché et al. 2017), they have not yet been used in the field of mathematics education research. We, therefore, want to extend our research and the according classification scheme developed by Klinger (2019) to cover this data as well.

### 3.3 Data Collection

We chose two apps available in the German Google PlayStore and three YouTube videos in German for further investigation.[1] This decision was taken in accordance with the apps' and videos' overall market shares, i.e., the number of downloads or individual views. To cover all relevant ages, one app and two videos focus mainly on contents of elementary school while one app and one video cover mainly contents of the secondary level.

For the primary level, we chose the videos "Written subtraction with multiple numbers" ("Schriftliches Subtrahieren mit mehreren Zahlen", 9,000 views; all following values retrieved 12/28/2019) and "Written division" ("Schriftliches Dividieren", 491,000 views) offered by the German YouTuber "Lehrerschmidt" with 338,000 subscribers. Lehrerschmidt covers mathematical topics from the elementary level up to the lower secondary level (as well as some topics of physics and general education). His videos are mostly single shot videos just showing his hands writing on paper while his voice offers explanations from the off.

Moreover, we chose the software "König der Mathematik Junior" ("King of Mathematics Junior", > 50,000 installations) as an app for the primary and early secondary level. The app offers simple, mostly arithmetical calculation tasks that are to be solved in the shortest possible time. The user starts with a character of lowest 'level' and can climb to a higher level by solving tasks to eventually become the "King of Mathematics". In this sense, the app can be seen as a gamified drill-and-practice learning opportunity.

For the secondary level, we examined the video "Quadratic functions" by the German YouTuber "Math by Daniel Jung" (1,380,000 views, 602,000 subscribers). His videos cover the lower and upper secondary levels of mathematics. He always stands in front of a non-interactive whiteboard visible from the chest up, offering explanations.

As an app covering the secondary level, we chose "Photomath", which is one of the most downloaded 'educational' apps with over 50 million installations on Android devices. Photomath is a so-called CAS-integrated smartphone app (Barzel et al., 2019), offering a scan function for mathematical equations, the relevant solutions, and the entire calculation process with some explanations (Klinger & Schüler-Meyer, 2019; Webel & Otten, 2016).

As a basis for further data analysis, we retrieved 1268 user reviews for these contents. The data was collected during September and October 2019. The total number of reviews taken into account resulted from saturation in our sampling process. Table 1 shows their distribution for the corresponding apps and videos.

| Level | Apps | Videos |
| --- | --- | --- |
| Primary | #1: King of Mathematics Junior https://play.google.com/store/apps/details?id=com.oddrobo.komj (111 reviews) | #3: Written subtraction https://youtu.be/2qmLcqPqfrQ (169 reviews) #4: Written division https://youtu.be/2A-9_-GCXrA (41 reviews) |
| Secondary | #2: Photomath https://play.google.com/store/apps/details?id=com.microblink.photomath (700 reviews, data set provided by Klinger 2019) | #5: Quadratic functions https://youtu.be/KEuNUgIiIyI (247 reviews) |

Table 1. Used apps and videos and number of related reviews analyzed

### 3.4 Data Evaluation

For data evaluation, we started with the classification scheme proposed by Klinger (2019). It was developed inductively and comprises the following five categories each user review can be sorted into: (1) Personal background, (2) Fields of uses, (3) Emotions and attitudes, (4) Perceived qualities of the digital learning opportunities, and (5) Perceived shortcomings of the digital learning opportunities. It should be noted that a review can also fall into several categories. Each category offers a variety of subcategories.

Since Klinger (2019) is limited to the app Photomath, it is unclear if these categories also cover all relevant reviews for apps of the primary sector and user comments on mathematical learning videos on YouTube. We, therefore, used these categories merely as a starting point for coding the reviews of the apps and videos and started validation. It turned out that the five dimensions mentioned above are, in fact, also good general categories for a classification scheme to analyze app reviews and video reviews. However, the classification scheme had to be slightly modified at the more specific level.

In the following, we will describe all five categories:

(1) Personal background:
Some reviews allow inferences about their authors' age, school level (primary or secondary), gender, etc.

(2) Fields of uses:
This category contains information on the context the app or video are used in. This covers the individual learning setting, such as doing homework, preparing for an exam, or cheating in the classroom.

(3) Emotions and attitudes:
This category covers information on the users' emotions and attitudes including motivational aspects, beliefs, and self-concept.

[1] All reviews presented as examples have been translated from German by the authors.

(4) Perceived qualities of the digital learning opportunities:
This category reports the perceived qualities of a certain app or video. This covers more general aspects like usability as well as deeper aspects regarding the possibility for efficient learning opportunities itself (cf. Barzel, Ball & Klinger, 2019).

(5) Perceived shortcomings of the digital learning opportunities:
This category is very similar to the previous one but investigates negative aspects like shortcomings. I t also covers more general as well as deeper aspects.

## 4. RESEARCH FINDINGS

Along the categories described in section 3.4, selected research findings of the investigation are presented in the following five sections. Exemplary reviews for the respective category are also attached and discussed to support the statements.

### 4.1 Personal Background

In this section, the personal background of the reviewers is discussed. Table 2 summarizes the data for this category, subdivided into videos and apps for the different school levels.

| | Videos: primary level (210 reviews) | Videos: secondary level (247 reviews) | All videos (457 reviews) | Apps: primary level (111 reviews) | Apps: secondary level (700 reviews) | All apps (811 reviews) |
|---|---|---|---|---|---|---|
| Primary school students | 5 | 0 | 5 | 3 | 0 | 3 |
| Secondary school students | 18 | 6 | 24 | 4 | 0 | 4 |
| Students (no school level mentioned explicitly) | 45 | 68 | 113 | 10 | 0 | 10 |
| University student | 1 | 1 | 2 | 0 | 4 | 4 |
| Teachers | 1 | 2 | 3 | 0 | 2 | 2 |
| Parents | 5 | 0 | 5 | 11 | 76 | 87 |
| Former students | 5 | 1 | 6 | 1 | 4 | 5 |

Table 2. Personal background of the reviewers

The digital learning opportunities with primary school content do not seem to be used primarily by primary school children. This is true particularly for the analyzed videos. In only five of the 210 reviews analyzed for the two primary school videos, information can be found that the users were attending primary school at the time the review was written (e.g., “Thanks to you, I’ll get into high school” on video #4). On the other hand, 18 reviews provide information on the users attending a secondary school form (e.g., “And 6 years ago it seemed so difficult to me 😛 😛” on video #4). It can be deduced from 45 reviews more that these are school students. Although no age and/or class level is stated, the users in these reviews indicate, for example, that they use the videos in or for learning purposes (e.g., “MY teacher explains it so complicatedly, but you explain it much better than my teacher does. Thank you so much.” on video #3). Furthermore, the language suggests that the vast majority of the 45 reviewers are secondary school learners. The purpose of using these videos essentially seems to be (re)addressing ununderstood or non-automated content for secondary school learners (e.g., “grade 9 and I finally got it” on video #4). On the other hand, those videos which are materially aimed at secondary school students also seem to be used by secondary school students.

Further analyses also show that school children are not only the main users of videos related to primary school content, but of all the videos analyzed. Only sporadic references could be found in the reviews that users had already completed their school careers. Two reviews indicate that university students reviewed the video, while three reviews offer indications that the reviewer is an active teacher. In addition, former students can be identified without any recognizable connection to a current role in teaching and learning mathematics (e.g., “This moment, when you, in your mid-30s, decide to give math a chance. Thanks for the video!” on video #4). Finally, five reviews show that parents used the videos (e.g., “I’ll watch it with my son. He has Dyscalculia” on video #4).

Overall, students seem to be the main user group of the mathematics-related videos for primary and secondary schools analyzed here. Seemingly, particularly learners in secondary school use the videos frequently – regardless of the content of the learning offers.

### 4.2 Fields Of Uses

After examining who the users – or reviewers – of the digital learning offers analyzed are, this section looks at what purpose the apps and videos are used for. Since school children represent the main user group of digital learning offers, the fields of uses identified here focus on typical activities of this clientele.

We can see from the total of reviews that users indicate they use digital learning opportunities primarily for *learning* (61 reviews) or *understanding* (100 reviews) mathematics (e.g., "great, understood everything just wow 😛" on video #5). However, content-specific analyses quickly show that they are hardly suitable for the purpose stated by the users (see sections 2.2, 2.3) and that there seems to be a different understanding of 'understanding' – an "illusion of understanding" (Kulgemeyer, 2018).

In addition, 80 of the 457 reviews for the videos indicate that the learning resources are being used to prepare for upcoming exams (e.g., "thank you, am writing a test tomorrow about it, I understand, thank you :-)" on video #3) and to improve grades (e.g., "Great video! Hopefully, I understood it and will get a good grade tomorrow" on video #5). This seems to be successful as some learners also review after exams and underline the usefulness of the apps and videos for the preparation of the exams (e.g., "Thank you, otherwise I would have messed up the math test" on video #4; "Thank you, LehrerSchmidt, I wrote a test and got an A, thanks 100 times" on video #4).

| | Videos: primary level (210 reviews) | Videos: secondary level (247 reviews) | All videos (457 reviews) | Apps: primary level (111 reviews) | Apps: secondary level (700 reviews) | All apps (811 reviews) |
|---|---|---|---|---|---|---|
| Learning | 11 | 4 | 15 | 1 | 45 | 46 |
| Understanding | 28 | 24 | 52 | 18 | 30 | 48 |
| Exam preparation and grade improvement | 24 | 56 | 80 | 0 | 19 | 19 |
| Completing homework | 1 | 0 | 1 | 0 | 43 | 43 |
| Dealing with learning obstacles | 0 | 0 | 0 | 0 | 22 | 22 |
| Checking results | 0 | 0 | 0 | 0 | 11 | 11 |
| Practicing | 1 | 0 | 0 | 7 | 0 | 7 |
| Cheating | 0 | 0 | 0 | 0 | 13 | 13 |
| Reprocessing content from the past | 20 | 0 | 0 | 0 | 0 | 0 |

Table 3. Fields of uses

The main field of use of the app Photomath seems to be completing homework. 43 reviews state that Photomath is used for this purpose. The users emphasize the practicability of the app and the reduction of the individual workload compared to the completing of homework in the past (e.g., "Really good app. Homework is now a piece of cake" on app #2). Other fields of uses include *dealing with learning obstacles* (22 reviews), *checking the results* (11 reviews), *practicing* (8 reviews), *cheating in test situations* (13 reviews), and *reprocessing content from the past* (20 reviews).

These findings on the specific fields of use can be an impetus for the discussion of the task and test culture in mathematics teaching and learning. However, the need to reflect on settings for the productive use of digital learning resources in the classroom – and not only for informal home use – is also clear (see section 5) (Klinger & Schüler-Meyer, 2019).

### 4.3 Emotions And Attitudes

Emotions and attitudes are also associated with the use of (digital) learning opportunities. Table 4 summarizes feelings and attitudes of reviewers regarding the apps and videos analyzed.

There is a consensus across *all* reviews regarding the various digital learning opportunities analyzed that using them is positive and helpful. A total of 51 reviews of the videos and 562 reviews of the apps give a *generally positive statement* about the respective digital learning offer (e.g., "It's just super, just super." on app #1). Furthermore, the developers of the videos (196 reviews) and the developers of the apps (63 reviews) are explicitly thanked for the development of the learning content (e.g., "Now that's what I call an innovation! [...] a big praise to the developers. Keep up the good work!" on app #2). Furthermore, the reviewers obviously feel supported by the videos (82 reviews) and the apps (152 reviews) (e.g., "thank you, helped me a lot" on video #3). Some reviewers even state that the preparation of the content is better than with their own teacher (e.g., "You are better than my teacher!!!!!" on video #4). This applies in particular to the videos (63 reviews), where, moreover, the personal approach of the video presenters is perceived as pleasant, entertaining, and/or suitable for the learning group (19 reviews, e.g., "The happy students who have you as their teacher" on video #5). Finally, it is also stated that mathematics is *fun* (again) through the digital learning content (16 reviews), that the preparation of the apps is *better than using a calculator* (8 reviews), and that the reviewers – feel *entertained*, at least with the videos (6 reviews).

| | Videos: primary level (210 reviews) | Videos: secondary level (247 reviews) | All videos (457 reviews) | Apps: primary level (111 reviews) | Apps: secondary level (700 reviews) | All apps (811 reviews) |
|---|---|---|---|---|---|---|
| Generally positive statement | 18 | 33 | 51 | 60 | 502 | 562 |
| Praise and thanks to developers | 106 | 93 | 196 | 1 | 62 | 63 |
| Support and assistance | 36 | 46 | 82 | 4 | 148 | 152 |
| Better than the teacher | 30 | 33 | 63 | 0 | 12 | 12 |
| Fun with mathematics | 1 | 0 | 1 | 11 | 4 | 15 |
| Better than the calculator | 0 | 0 | 0 | 0 | 8 | 8 |
| Entertainment | 2 | 4 | 6 | 0 | 0 | 0 |

Table 4. Emotions and attitudes

## 4.4 Perceived Qualities Of The Digital Learning Opportunities

In section 4.3, we saw that most reviewers have a predominantly positive attitude towards the digital learning opportunities. This is not necessarily surprising, especially since the apps and videos used in this study are very popular. Furthermore, the reviews also provide indications as to *why* the digital learning offers are frequently used and positively rated by referring to individually perceived qualities of the apps and videos. Table 5 summarizes the users' key responses.

| | Videos: primary level (210 reviews) | Videos: secondary level (247 reviews) | All videos (457 reviews) | Apps: primary level (111 reviews) | Apps: secondary level (700 reviews) | All apps (811 reviews) |
|---|---|---|---|---|---|---|
| High quality of explanations | 29 | 60 | 89 | 0 | 54 | 54 |
| Pleasant teacher personality | 11 | 8 | 19 | 0 | 0 | 0 |
| No obligation to learn | 1 | 0 | 1 | 0 | 0 | 0 |
| Playful design | 0 | 0 | 0 | 18 | 0 | 18 |
| Saves time | 0 | 0 | 0 | 0 | 3 | 3 |

Table 5. Perceived qualities of the digital learning offerings

We notice comparatively numerous mentions of the high quality of the explanations, which are particularly evident in the videos (89 reviews, e.g., “Very good explanation, slow and detailed. Keep it up!!“ on video #5) and the app with secondary school content (54 reviews, e.g., “Simply an extremely good app. It explains perfectly how to solve the tasks you did not understand :-)” on app #2). 63 of these 143 reviews do not only emphasize the quality of the explanations, but also attest a better explanation quality than that of the (current or former) teacher in the subject mathematics (e.g., “You simply explain it better than my teacher!!!” on video #4). The lack of reference to the quality of explanation in the analyzed app with primary school content can be explained by the fact that it is a training app without extensive explanations of the content of the tasks set and completed.

One category which could also be observed especially in the videos containing mathematics, is the mention of the pleasant personality of the person explaining. 19 reviews refer to the fact that they like the explaining teacher in the video (e.g., “Really cool teacher” on video #3). Finally, one review positively emphasizes that the video format no longer forces learners to acquire content but allows them to deal with the content voluntarily.

Two categories were only addressed in connection with the analyzed mathematical apps. On the one hand, 18 reviews in app #1 refer in a positive way to the playful design of the app, which is not the case for the other digital learning offerings. On the other hand, 3 reviews state that app #2 Photomath saves a lot of time because it displays solution steps and solutions at the push of a button.

All in all, the data in Table 5 above indicate that surface features are the main reference when describing perceived qualities of digital learning opportunities. However, hardly any references are made to content – for example, *why* an explanation is considered appealing from a content-didactic point of view. In this context, the statement *that* the explanations offered are perceived positively is usually maintained.

### 4.5 Perceived Shortcomings Of The Digital Learning Opportunities

After the question of perceived qualities was examined in the previous section, the question arises whether – and if so, which – shortcomings of digital learning offerings are addressed and identified in the reviews. Since only a few shortcomings or criticisms were stated by the users, we will not include a summary table here as in the other sections of the results chapter. Instead, some exemplary reviews of the digital learning offers are presented and commented on by way of example.

With regard to the analyzed apps, it can be stated that primarily surface features are addressed. *King of Mathematics Junior* (app #1), which can be characterized as a training app, is negatively assessed since the trial version of this app has *too little content and tasks* (“few, few tasks”), tasks are perceived as *too easy* (“Is the APP also available in harder?” on app #1), and that the unlocking of the full version is *not free* (“well cool, but unfortunately you have to pay”). Only one review specifically states that the app seems to be *not very suitable for learning* due to the low-threshold task difficulty (“Very simple tasks and hardly any demand, in my opinion it is not good for learning”). Photomath (app #2) shows shortcomings primarily regarding *usability and functionality* of the app. Some reviewers mention that the *app cannot solve word problems* (“It’s a pity that the app can't solve word problems”) or that there are *problems with the camera*, especially with focus and character recognition (“Automatic recognition by camera does not always work perfectly”).

In a similar way, perceived shortcomings are addressed in the analyzed videos. For example, one reviewer points out that there is a mismatch between the spoken number word and the written number sign in the video (“1301 he says, but writes 1311. Despite the small mistake, it is a good video and well explained. Nobody is faultless.” on video #4). This is more a minor flaw than a central didactic question. Moreover, five users state that they *did not understand* the content despite watching the respective video (“you are really cool but I still did not understand it 😞” on video #4). Three users formulate further questions that are indirectly related to the content of the respective video. Only occasionally, substantial questions are asked which reveal didactic deficiencies “Why do you calculate 14 - 1 - 1 in written form? You can do that simply in your head” on video #3).

If negative aspects are mentioned at all, the focus is on surface characteristics with both, the perceived shortcomings and the perceived qualities of digital learning offers. Demanding and valuable, detailed questions of content are hardly ever addressed in the reviews.

## 5. SUMMARY, DISCUSSION, AND OUTLOOK

### 5.1 Summary

In this paper, we investigated how frequently used mathematics apps and videos with content for primary and secondary school are evaluated by their users. In particular, it was analyzed (1) who uses these digital learning offerings, (2) how and for what purpose they are used, (3) which feelings and attitudes are associated with their use, and which (4) qualities and (5) shortcomings are subjectively perceived by the users. For this purpose, we used freely available user reviews on the web.

The results indicate (1) that digital learning opportunities are primarily used by secondary school students – even the apps and videos with primary school content. Regarding (2), learners indicate that they use the analyzed apps and videos to *learn* and *understand* mathematics, even though this seems difficult to achieve given the content of the digital learning opportunities – an “illusion of understanding” (Kulgemeyer, 2018) seems to exist. Furthermore, digital learning offerings are used primarily for exam preparation and the completion of homework. For (3), it can be stated that the use of digital learning offerings is perceived positively, and the developers are expressly thanked. This may be related particularly to the frequently mentioned supportive character of the learning opportunities. (4) Perceived qualities, particularly in the case of the videos, are often the explanations, which are subjectively considered of high quality – some even rated better than those of the teachers (Klinger, 2019) – and the 'teacher personality' of the videos' presenters, which is perceived as pleasant. In the app with primary school content, surface features such as the playful design or time savings are named. Regarding the (5) perceived shortcomings, it can be noted that didactic questions about the concrete content of the apps and videos are addressed only in a few cases. Here, the mention of surface features also dominates.

### 5.2 Discussion

The data collected in this study provides valuable insights into the views on and usage of digital learning opportunities widely used on primary and secondary school levels. In contrast to typical empirical studies, no fieldwork is required to collect data. Valuable data are used which are freely available to the general public on the Internet.

Although the project pursued here has proven to be economic from a methodological point of view, it is comparatively less controlled than other research in mathematics education in which specific target groups are systematically investigated, for example, by means of written questionnaires or in interview studies. In particular, the truthfulness of the information the users provide must be trusted. We believe that this is the case with a large number of reviews since there is no individual gain from untruthful reviews. Nevertheless, individual false statements cannot be excluded.

Although the number of reviews analyzed – 1268 – seems large at first glance, it should be interpreted in relation to the actual users of the apps and videos. The apps analyzed in this study were installed far more frequently and the videos had far more views (e.g., app #2 > 100,000,000 installations; video #5 > 1,600,000 views). In that sense, the sample used here is by no means representative. For example, the sample could be biased in the sense that particularly positive opinions predominate, while critical voices tend to act with restraint and do not comment. In addition, the finding that it is mainly secondary school students who write reviews may be due to the fact that they are more likely to be able to write reviews at all. Nevertheless, one might expect that at least parents whose children regularly use such learning opportunities would write corresponding reviews. Since we could not detect a significant amount of such reviews, we see our thesis further supported.

Despite this, it should be acknowledged that all information on user groups could be biased if one group systematically less frequently reveals their affiliation to one of the groups or even never writes reviews at all. All in all, the findings described are to be interpreted as hypotheses that can be pursued more systematically in controlled investigations. In this sense, the present study is of exploratory character as already mentioned above.

Furthermore, the data must also be interpreted against the background of the respective digital learning opportunities. In this study, we have only examined a few frequently used apps and videos for primary and secondary schools. Although we believe that the digital learning opportunities used are representative of those learning opportunities currently provided on common video platforms and app stores, the results certainly depend on the concrete, in-depth content design of the digital learning opportunities.

Despite all these limitations of the study, the tendency identified in the results should also be taken into account. We consider the finding particularly noteworthy that didactically rather questionable learning opportunities are used for exam preparation and that apparently successfully. Numerous comments could be found that explicitly relate the success of the exam and the exam preparation to the respective medium. Therefore, we argue that the reviews can also provide insights into the currently prevailing teaching culture and task culture in examinations. If the large proportion of examination tasks were to focus primarily on understanding rather than superficial procedural knowledge, we do not believe that students would achieve the success that has obviously been achieved. Comprehension-oriented teaching could, thus, contribute to having more videos containing mathematics of the *Explain-Why*-type. This could potentially contribute to a balance of videos of different explanation types (see section 1.3).

### 5.3 Outlook

The points for debate raised in Section 5.2 also represent starting points for further work with digital learning offerings in research and practice:

In our view, an investigation of further apps and videos in a systematic setting seems desirable for *research in mathematics education.* This way, further valuable insights into the ways of thinking of users and the ways in which digital learning opportunities are used could be gained. Furthermore, we see a significant need for further development to cover the entire content range of primary and secondary schools with didactically high-quality digital learning opportunities. Mathematics didactics must, therefore, dedicate itself far more than to date to the didactically sound design of apps and videos containing mathematics for all phases of the learning process.

For the use of the analyzed digital learning offers in teaching practice, there is sometimes still a lack of elaborated concepts that can promote productive ways of use - and not only calculation. First approaches to the use of the Photomath app can be found, for example, in Klinger and Schüler-Meyer (2019). However, it is, as yet unclear how the mathematics videos, which are currently widely used in non-formal and informal settings, can be dealt with in formal settings in the classroom. From our point of view, this seems quite possible, for example by showing students relevant video sequences at the end of a lesson and asking them to identify subject-related shortcomings. This approach could lead to a more critical attitude towards digital learning opportunities, instead of uncritical and unreflected use, possibly due to the overwhelming number of positive reviews in the app stores. It also seems possible to develop 'good' explanatory videos together with the students (c.f. Leinigen, 2020) and videos that also encourage exploration and reasoning (c.f. Römer & Nührenbörger, 2018). Still, how students proceed in this also needs to be investigated on the basis of research.

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