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Reconstruction of opportunities to understand the function concept from online explainer videos

Martin Ohrndorf¹, Insa Meißner^{1,2}, Florian Schmidt-Borcherding² and Maike Vollstedt¹

¹University of Bremen, Faculty of Mathematics and Computer Science, Germany;
ohrndorf@uni-bremen.de

²University of Bremen, Faculty of Pedagogy and Educational Sciences, Germany

The use of online explainer videos plays an important role as an opportunity to learn the function concept. Yet, there is limited research on whether explainer videos foster conceptual understanding of functions. This article presents a qualitative examination of four online explainer videos for introduction to functions from different online platforms. By integrating explainer videos into an opportunity-to-learn model, we can examine the instructional explanations from explainer videos as learning opportunities. Using a deductive coding system based on the understanding model of the function concept, we reconstruct opportunities to understand the function concept from explainer videos. Our results show that all opportunities to understand the function concept can be reconstructed from the videos, although the four videos vary in the opportunities offered.

Keywords: Explainer videos, understanding model of the function concept, opportunity-to-learn models, instructional explanation.

Introduction

The use of online explainer videos (e.g., via online learning platforms) plays an important role as a learning opportunity for school-based teaching and learning processes (FORSA, 2020). The great importance of explainer videos is reflected in the increased use of both teachers and students over the past years (FORSA, 2020). In Germany, for instance, more than 45% of the teachers have increased their use of explainer videos in distance learning since the Covid-19 pandemic and utilize explainer videos as the second most common exercise format after exercise sheets (FORSA, 2020). In particular, explainer videos dealing with mathematics take the leading position among different school subjects in terms of frequency of use: more than one-fifth of students utilize mathematical explainer videos at least once a week (Wolf & Kulgemeyer, 2021).

The frequent use is also reflected in the high number of views and subscriptions to popular YouTube channels on school mathematics topics (Korntreff & Prediger, 2021). According to a qualitative evaluation of 1941 mathematical YouTube videos, videos from the content area of functions, in particular, generate a high level of interest (Bednorz & Bruhn, 2021). In addition, explainer videos offer a rich variety of representational opportunities of functions through multimedia (Mayer & Fiorella, 2022). It is not yet known whether the high level of interest in the content area of functions or the rich representational opportunities for functions in explainer videos foster conceptual understanding of functions. In response to this desideratum, we present an exemplary examination of four explainer videos from the domain of functions with regard to their opportunities to understand. In this paper, we address the following research questions (RQs):

RQ1: To what extent can opportunities to understand the function concept be reconstructed from online explainer videos?

RQ2: To what extent do the four explainer videos vary in their opportunities to understand functions?

To answer these RQs, we developed a deductive coding system from the understanding model of the function concept according to (Zindel, 2019) and applied it to four explainer videos.

Theoretical framework

Instructional explanations in explainer videos

Explainer videos are audio-visual media in which concepts and their relationships are explained (Klinger & Walter, 2022; Korntreff & Prediger, 2021; Schorn, 2022; Wolf & Kulgemeyer, 2021). Explainer videos are investigated from different perspectives, e.g., media research (Schorn, 2022) or subject matter education (Korntreff & Prediger, 2021; Wolf & Kulgemeyer, 2021). Within subject matter education, explainer videos are classified on the basis of instructional explanations (Klinger & Walter, 2022; Leinhardt, 2001). Instructional explanations have the goal to communicate subject content to other people (Leinhardt, 2001). Instructional explanations can be conveyed by media (e.g., books or computers), persons (e.g., teachers) or they can be included in plenary discussions (e.g., class discussion of tasks) (Leinhardt, 2001). Based on their learning opportunities, they are divided into three types: explain-how (instructions or procedures), explain-what (factual explanations or definitions of terms), and explain-why (explanations of connections between different terms) (Klinger & Walter, 2022). According to Korntreff and Prediger (2021), explainer videos are instructional explanations in the form of produced audio-visual media.

Instructional explanations provide learning opportunities within learning environments (Wittwer & Renkl, 2008). In describing and analysing learning environments within empirical classroom research, opportunity-to-learn models are considered ‘state of the art’ (Seidel, 2014). Opportunity-to-learn models involve students’ individual use of learning opportunities from instruction in interaction with their learning outcomes (Seidel, 2014). Following this cognitive constructivist approach, explainer videos (or rather their instructional explanations) can be understood as learning opportunities within teaching and learning processes (Ohrndorf, 2021). By integrating explainer videos into opportunity-to-learn models, we are able to analytically separate explainer videos as learning opportunities on the one hand and the use of these learning opportunities on the other. In this article, explainer videos are examined exclusively in terms of their learning opportunities.

Explainer videos offer a rich set of learning opportunities in the form of representation of functions through multimedia (Mayer & Fiorella, 2022). The simultaneous multimedia depiction of multiple representations enables synchronous linking (Goldin & Kaput, 1996). Due to the rich set of external representations of functions including their possible synchronous linking in explainer videos, functions are the ideal content area to study in relation to explainer videos.

Comprehension elements of the function concept

Mathematical objects can only be represented by external representations because, unlike objects in other disciplines, they cannot be perceived directly or demonstrated by experiment (Duval, 2006)

This holds also true for functions. Functions can be represented by external representations, e.g., verbal, symbolical, numeric, and graphic (Goldin & Kaput, 1996; Swan, 1985). Thinking about and communicating with external representations of functions conditions and promotes functional thinking, i.e., a way of thinking that is typical for dealing with functions (Vollrath, 1989). Three aspects of the function concept are useful in differentiating functional thinking: correspondence, covariance, and mathematical object (Doorman et al., 2012; Vollrath, 1989). To foster functional thinking it would be an important learning goal that learners are able to link on the one hand various types of functions in regards to their aspects and on the other hand with different representations of functions (Zindel, 2019). Difficulties in this linkage can be explained by the predominance of specific characteristics like individual representations and the implicitness of the conceptual core, which is common to all representations of the concept of function (Zindel, 2018, 2019).

The core of the function concept can be understood with the help of the three-level understanding model of the function concept (Zindel, 2019). The first level is the location of the concept of function itself. It is embedded in a network with related concepts such as magnitude or variable. These concepts include respective sub-concepts, such as the three aspects of the function concept (Doorman et al., 2012; Vollrath, 1989). On the second level, the various representations of functions are located (Goldin & Kaput, 1996; Swan, 1985). The third level is the facet model including its comprehension elements (Figure 1).

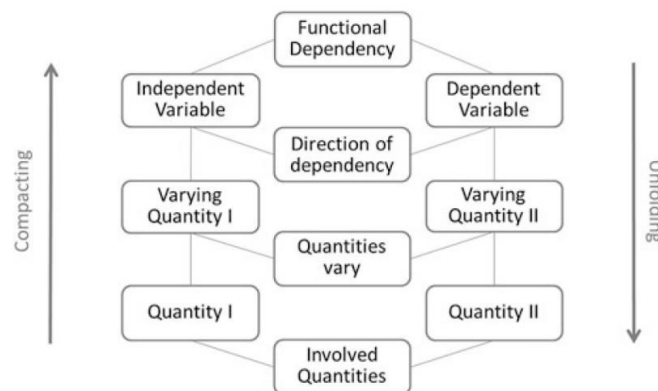


Figure 1: Third level of the understanding model of the function concept, i.e., the facet model to the core of the function concept (Zindel, 2018, p. 79)

The facet model is based on the cognitive psychological assumption that conceptual knowledge consists of a mental network (Drollinger-Vetter, 2011). This mental network is divided into several interconnected comprehension elements, the facets of the concept (Drollinger-Vetter, 2011). These facets must be flexibly compacted and unfolded depending on the learning situation (Drollinger-Vetter, 2011). The facets of the core of the function concept are important for all representations of functions and all types of functions (Zindel, 2018, 2019). The facet model, read from bottom to top, explains how the facets are compacted. Its basis is that there are (at least) two quantities involved, quantity I and quantity II. These quantities could have the property that they each vary, varying quantity I and varying quantity II. These varying quantities could further have the property that one quantity is directionally dependent to the other, independent variable and dependent variable. This dependency can be functional. According to the situation in which functions are handled, the facets

must be flexibly unfolded (top-down) and compacted (bottom-up) (Zindel, 2018). These facets form the facet model to the core of the function concept, the third level of understanding model of the function concept. In summary, Zindel’s (2019) three-level understanding model of the function concept provides a framework to examine opportunities to understand functions.

Research design and methods

Our data corpus for the analysis of opportunities to comprehend the function concept consists of four online explainer videos. Comparability at the content level is provided by narrowing the focus to introductions of the function concept. The videos were selected from video platforms that are part of German students’ everyday life (YouTube and Sofatutor). On YouTube, we selected three German math video channels based on the number of subscribers (Korntreff & Prediger, 2021). From each of these video channels, one video was selected based on the number of views, which provides an introduction to the function concept. In addition, we included one video from Sofatutor, an online learning platform with more than 10.000 explainer videos that is widely used in Germany (Table 1).

Table 1: Data corpus of the four explainer videos with sources (last accessed on February 14, 2023)

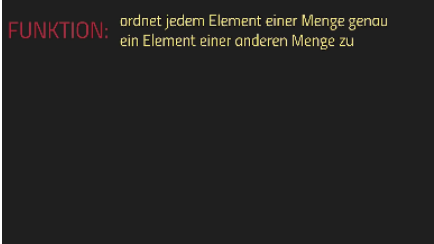
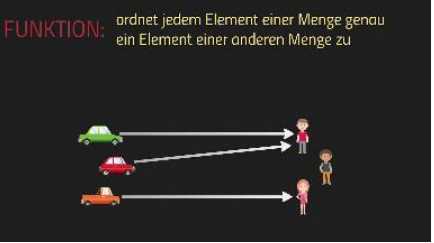
No	Channel	Subscribers	Views	Publication date	Video ID on YouTube (https://www.youtube.com/watch?v=) and on Sofatutor (https://www.sofatutor.com/mathe/matik/videos/)
V1	Sofatutor	-	-	-	was-sind-funktionen-ueberblick
V2	Mathe by Daniel Jung	885.000	735.444	June 24, 2013	tywU-wn6tF4
V3	Mathe-simpleclub	818.000	1.001.525	February 7, 2016	myLx0d5wmHw
V4	musstewissen Mathe	72.000	202.030	January 1, 2018	ng1-04ka2Zs

The four explainer videos (V1-V4) were first verbally transcribed. The transcript together with screenshots of the video frames were then analysed within the framework of qualitative content analysis (Mayring, 2010). The deductive system of categories used for data analysis is based on the three-level understanding model of the function concept with facet model (Drollinger-Vetter, 2011; Zindel, 2019). Two experts coded three of the four videos consensually. The fourth video was coded separately, resulting in moderate agreement (Cohen’s kappa $\kappa = 0.6$). Those passages with formerly differing interpretations were subsequently discussed and then consensually coded. Thus, there is one final coded version of each video.

Exemplarily, Table 2 presents a coded excerpt from the transcribed explainer video V3 (translated literally from German by first and second author). In the first coding unit of the excerpt (Table 2, 1:13-1:20: “It [a function] assigns to each element of a certain set exactly one element of another set”), the explainer provides a verbal definition of a right-unique and left-total correspondence. It is, thus coded on level 1 with the correspondence aspect, specifying the correspondence right-unique

and left-total, on level 2 as verbal and on level 3 as functional dependency. In the second coding unit of the excerpt (Table 2, 1:20-1:28: “In this case, it assigns a car owner to each car”), the explainer video provides a conversion from the mathematical definition to the factual example. It is, thus coded on level 1 with the correspondence aspect, specifying the correspondence right-unique and left-total, on level 2 as verbal, arrow graphic and on level 3 “cars” as independent variable and “owner” as dependent variable.

Table 2: Coded transcript excerpt from Video V3 by Mathe-simpleclub

Time	Video frames	Verbal Transcription	Codes
1:13 1:20	(Function: assigns to each element of one set exactly one element of another set) 	A function does exactly that. It assigns to each element of a certain set exactly one element of another set.	1. Correspondence aspect; Right-unique; Left-total; 2. Verbal 3. Functional Dependency
1:20 1:28	(Function: assigns to each element of one set exactly one element of another set) 	In this case, it assigns to each car a car owner. [...]	1. Correspondence aspect; Right-unique; Left-total; 2. Verbal; Arrow graphic 3. Independent Variable, Dependent Variable

Results

In the sense of the first research question (RQ 1), the deductive system was used for data analysis to determine to what extent opportunities to understand the function concept can be reconstructed from online explainer videos. In total, the four videos result in 166 coding units. In the following, we present the results according to exemplary opportunities to understand on the three levels of the understanding model of the function concept (Zindel, 2019).

The first level of the model is divided into the three aspects of the function concept (correspondence, covariance, and mathematical object) and two mathematical properties of functions (right-unique and left-total). All aspects and properties could be reconstructed: the aspects of correspondence (e.g., Table 2, 1:20-1:28), covariance (e.g., V4, 6:10-6:26: “[...] a list of digits, i.e., x-values, to calculate the associated function values. This is how you see the change in function values [...]”), and mathematical object (e.g., V1, 4:12-4:18: “For example, the graph could be point symmetric to the origin”) as well as the properties right-unique and left-total (e.g., Table 2, 1:13-1:20).

The second level is divided into the four representations of functions, which also all could be reconstructed: verbal (e.g., Table 2, 1:20-1:28), symbolical (e.g., V2, 0:22-0:30: “So we have f as a function that is, colon, described by x goes over into two x minus four”), numerical (e.g., V2, 2:58-3:03: “To understand what a function is exactly, one often gives a table of values”), and graphic representations (e.g., V4, 2:58-3:03: “Then you try to connect the dots in a meaningful way. Most of the time, the result is a nice smooth curved line”). In addition, the symbolic, numerical, and graphic examples are also shown visually in the video frames (e.g., Table 2, 1:20-1:28).

The third level is divided into the comprehension elements, which, again, all could be reconstructed in our video corpus: quantity I and quantity II (e.g., V4, 3:50-3:56: “[...] the definition set and the target set consist of numbers”), varying quantity I and varying quantity II (e.g., V1, 3:03-3:15: “Often, one is interested in the value of the functions when x equals 0. Which other values of the variables one looks at depends heavily on the function. We'll just put in a few”), independent variable, dependent variable, and functional dependency (e.g., Table 2, 1:13-1:28). In summary, all opportunities to understand of all three levels of the understanding model of the function concept could be reconstructed from the four selected videos.

In the sense of the second research question (RQ 2), the deductive system was used for data analysis to determine to what extent the four explainer videos vary in their opportunities to understand functions. In line with RQ1, the results of RQ2 are also presented according to the opportunities to understand on the three levels of the understanding model of the function concept (Zindel, 2019).

With respect to the first level, only V4 contains all three aspects of the function concept and both mathematical properties of functions. In contrast, V1 misses both mathematical properties of functions (left-total, right-unique), V2 misses one (right-unique) of two mathematical properties of functions, and V3 misses two (correspondence and covariance aspect) of the three aspects of the function concept and both mathematical properties of functions. With respect to the second level, again, only V4 contains all four representations of functions. V1 and V2 miss the verbal representation, whereas V3 misses the numeric representation of functions. With respect to the third level, V1 and V4 contain all comprehension elements. V2 misses quantity I, quantity II and functional dependency, and V3 varying quantity II. In summary, opportunities from all three levels could be reconstructed from all four selected videos. Nevertheless, the videos vary in their opportunities. The variance ranges from video V4, from which all eighteen opportunities could be reconstructed, to video V2, from which only eleven opportunities could be reconstructed.

Discussion and outlook

Our study shows that it is possible to reconstruct opportunities to understand the function concept from online explainer videos. With respect to all three levels of the understanding model of the function concept (Zindel, 2019), we were able to reconstruct opportunities to understand from the four selected videos. In line with Zindel (2019), the understanding model of the function concept can be used as an analysis tool. While Zindel (2019) uses the model to analyse learning pathways, our results show that the model can also be used to analyse explainer videos with respect to their opportunities to understand functions. Zindel's (2019) model is limited to analyse opportunities to understand functions exclusively conceptually. This indicates that we have analysed the explainer

videos (or rather their instructional explanations) only in respect to explain-why and explain-what (Klinger & Walter, 2022). The explain-how type of instructional explanations was not considered. By extending Zindel's (2019) model by including the perspective of explain-how, a more extensive analysis of explainer videos based on their opportunities to understand functions is possible.

In terms of integrating explainer videos into opportunity-to-learn models (Ohrndorf, 2021), we were able to reconstruct learning opportunities from explainer videos. This reconstruction indicates that explainer videos could foster conceptual understanding of functions. Following the opportunity-to-learn model (Seidel, 2014) the next step is to examine whether students use these learning opportunities to understand the function concept.

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