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What Constitutes an Intelligible Argument in the STEM Fields?

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ABSTRACT: Science communication in the format of digital presentations aims to make knowledge accessible e.g., in STEM fields. The multimodal nature of scientific presentations raises the question of how argumentations must be specifically designed to achieve the stated goals. Research shows that when presenting complex content, it is helpful to resort not only to verbal but also visual means. In this paper we address the characteristics that visualizations require to add significant value to the argumentation.

KEYWORDS: argumentation, concept mapping, evidentia, multimodality, presentation, presentation competence, rhetoric (of science), science communication, STEM fields, visual arguments

1. INTRODUCTION

Scientists are looking for answers to questions that in many cases have social relevance. They share their answers in their scientific community. But their findings must find their way to a broader public, especially in democratic systems and in the age of "alternative facts" (Broks, 2017). Only in this way can participation be made possible; can citizens understand political decisions made based on research. Science communication for different target groups is a democratic issue (Akin, 2017).

An important communication format of science communication is the multimodal digital presentation, which is used at universities (Bucher & Niemann, 2012; Stark & Paravel, 2008), in public lectures and in more innovative formats, such as Ted Talks (Foung & Kwan, 2022; Kjeldsen, 2013) or Science Slams (Niemann et al., 2020), to the wider public. At scientific conferences e.g., at the annual Nobel Laureate Meeting, young outstanding scientists present their research and projects not only to other scientists, but also to the press and to foundations that might support the research. These formats have in common that excellent scientists share and recontextualize their findings. But does excellent research result in equally excellent multimodal science presentations? What makes multimodal argumentation in scientific presentations a situation in which sharing scientific knowledge succeeds? How can we support our students to come up with good multimodal arguments that lend themselves to digital presentations? For these questions rhetorical considerations are relevant as well as the interdisciplinary perspective. We argue that multimodal forms of argumentation in science communication have a long history and are constantly evolving with technological and media possibilities. We also look at digital presentations and ask what the benchmarks for successful knowledge communication are. Finally, we address the promotion of presentation skills, especially multimodal argumentation. Here we present the approach of Youth presents in more detail.

2. MULTIMODAL ARGUMENTATION: NOT A NEW PHENOMENON IN SCIENCE COMMUNICATION

Groarke points out in his article that "[d]uring the last decade, one source of debate in argumentation theory has been the notion that there are different modes of arguing that need to be distinguished when analyzing and evaluating arguments." (Groarke, 2015, p. 133) Therefore, it is important to clarify what is meant by argument or argumentation in this article. The use of these terms does not just mean persuading the addressee. The terms used here have a broader meaning that includes explanation and the aim of communicating knowledge, promoting understanding and insight into research and science. "Argumentation, in whatever sense it is conveyed, is an integral part of science and we argue it should be integrated into science education" (Jiménez-Aleixandre & Erduran, 2007, p. 3) Knowledge communication involves just as well claims to legitimacy, reasons, plausibilisation, and even the use of the triad of ethos, logos and pathos, to explain and prove how and why things work. Therefore, our focus is not on pros and cons or (persuasive) arguments in debates, but on explanations in knowledge-communicating multimodal presentations in STEM fields. Specifically, it is about the competence of students or learners to present their knowledge of STEM subjects in a multimodal approach, by digital presentations.

Multimodal modes of argumentation and representation, such as the combination of text and image, are a particular way of communicating and organizing knowledge in the natural sciences, as we can already see in Alexander von Humboldt's various written and drawn works. The concrete form of rhetorical techniques is, after all, also an expression of our thinking, presented in descriptive texts and visualizations (Humboldt, 2014; Humboldt et al., 2019). Humboldt expresses his scientific findings, he illustrates his results, he makes numerous details accessible e. g., details of the condor. He makes three drawings of the condor, two of which show details of the head and the claws. Humboldt did not stop at drawing. In his work "Animal Worlds" he presents his findings in form of long textual explanations (Humboldt et al., 2019). On the level of visual modality, he shows in detailed passages the plumage of the condor, the arrangement of the feathers, the shape of the head and much more. Regarding science communication, this is related to the decision of what needs to be illustrated, because it is of outstanding importance for scientific discourse.

On each of these modalities he applies the rhetorical principle of evidentia. This means that ideas are evoked by linguistic means (Koch & Schirren, 2016, p. 224). In ancient rhetoric, the richness of detail in terms of the composition of the text is subsumed under the term enárgeia, which is ultimately intended to support the argument of the speaker (Lipphardt, 2019, p. 85f.). A multimodal approach was already characteristic of the orator's action in antiquity. Rhetorical theory does not focus solely on the verbal modality. The spatio-temporal dimension, the moment of the speaker's performance, led in classical rhetoric to extensive reflections on body language and voice (Koch & Schirren, 2016, p. 223f.). The persuasive value of visual means in the context of the presentation of evidence is also clear, for example in the remarks of Quintilian (Quintilien & Rahn, 1972 VI 1, 30f.). There are still useful rhetorical techniques to be derived from this for today's communication problems. On the one hand, this means that the scientific facts are described in such detail that they are almost before your eyes. But it also means liveliness.

The condor becomes almost alive through the linguistic descriptions. Both modalities, visuals und verbals, are important for his scientific argumentation and contribution to gaining knowledge. In sum, image and text belong together, there's an interplay between different modalities: "thus I believe I am doing science a service by making public the detailed description and drawings I have sketched of the Condor on the spot." What can be observed in this example is the use of rhetorical techniques in a way that was medially possible at the time.

Media possibilities have always provided the framework for rhetorical actions and both forced and enabled the communicator to adapt and widen the media-specific principles (Knape, 2012). They are critical for which visualizations are and can be used to convey knowledge. The "Friendly's Milestones Project" (Friendly & Denis, 2001), which itself visualizes the history of data visualization, shows developments of statistics, cartography, graphic recording etc. It shows three aspects very well that are important for multimodal argumentation not only in the field of science communication: First, certain technologies are essential to measure, record and collect data in the first place – technology, which allows "(a) reproducing and publishing data graphics using color, (b) recording raw data for more than one variable at a time, and (c) tabulating or calculating some summaries that could then be displayed in graphs." (Friendly & Wainer, 2021, p. 159) Secondly, it shows that creative ideas about how this recorded and collected data can be shown and visualized, are crucial. Thirdly, the scopes of collected and visualized data "on social problems (crime, suicide, poverty) and disease outbreaks (cholera)" (Friendly & Wainer, 2021, p. 161) that led to an increase in graphs indicate their initial purpose, what they are still used for and what they are most beneficial for: To translate raw data, numbers and facts, often of social relevance, into more easily understandable visualizations so that this knowledge can be communicated to a wider public. It is, from the beginning: science communication.

Since more and more technologies emerge that can measure, collect, process, correlate and show information in a wide variety of modes, since we "live on islands surrounded by seas of data" (Friendly & Wainer, 2021, p. 1) that are getting bigger and bigger, it is all the more important not to lose focus. These vast amounts of data and modes open up completely different possibilities for thought structures, for asking questions, wondering how the world works, and the transfer of knowledge.

Humboldt, for example and as already mentioned, made drawings, and included detailed descriptions. For his drawings and descriptions, he had to rely on observations, on his senses, and he had little technical equipment - at least from today's point of view. It is obvious that he might have emphasized and examined different details, other facets, if he had had access to more advanced, our modern equipment. If he had lived in our times, for example, with the possibility of using high-resolution, high-speed cameras with the best microphones, he might have focused on the soundlessness of the of the wings of some bird species, such as the owl - and then asked himself what the cause of this soundlessness could be. He could then have pursued this leading question with the help of an electron microscope, for example, and made visible the structures that make possible the so-called laminar air flows which significantly reduce sound.

In short, these seas of data must be understood, selected, sorted, and arranged by the person who needs to have a guiding question and wants to explain or show something. The guiding question is decisive for which data are selected and used, which modalities are used to convey the acquired knowledge and which meaning is assigned to them – and this always with a view to the addressees. Having this goal, answering the guiding question and transferring knowledge to the audience, in mind determines how knowledge is to be organized. The goals determine which forms and elements come together in such a way that they best illustrate or convey what is to be shown or clarified.

However, all this assumes that the central or guiding question is very clear to the person presenting, that certain scientific principles are known, in short that the arguments within the explanations are recognized. But this is exactly the problem for students and learners. It is one of the most challenging issues for students to identify where the argument actually lies and the best way to get to the answer of the guiding question.

All in all, these are the major challenges of argumentation. To counter them, argumentation researchers have long visualized arguments in basic patterns, through a so- called path analysis (Denis, J. & Legerski, 2006). Groarke for example used what he called “a ‘Key Component’ (KC) table and a corresponding diagram to clarify the content and structure of the argument proposed in a particular act of arguing” (Groarke, 2015, p. 135). Depending on the theory and the researchers, these patterns may vary, but each pattern is an example of both the elements that make up an argument and how those elements relate to each other.

To make it clear to students how arguments and argumentation works, we have implemented and established the visual technique of causal modeling, or concept mapping - again, a well-known and useful technique that has been adapted many times in the past. It is a method that has been shown (Hay et al., 2008; Khajeloo & Siegel, 2022) to increase students' ability to systematically identify the argument itself, and then to define and keep the guiding question not only in mind but in front of their eyes. It allows them to organize, sort, and integrate relevant information, to recognize the main structures of an argument in a text or in the topic they want to talk about. The concept we are referring to, and the individual elements that constitute it, are the work of Youth Presents and have been developed to enhance students' presentation skills. It consists of elements that are relatively easy to identify, since it is intended to help learners: Firstly, there has to be a guiding question or a phenomenon to be explained, which, as mentioned above, forms the beginning and the end of the mapping process; secondly, the causal factors that establish the link between the third element, the identified regularities such as laws of nature, rules, etc.

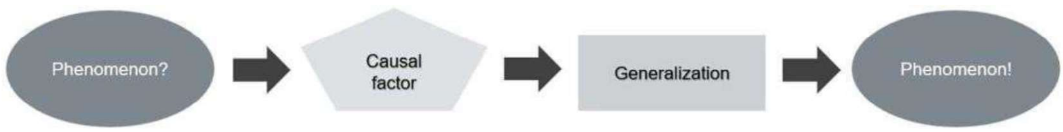

Figure 1: Path diagram

Hence, these first steps, identifying, to be able to recognize the argumentative structure leading to the answer, is crucial for understanding and reconstructing the argument. It is the basis for the next step, for preparing a presentation that explains the phenomenon in the best way possible. The scientific explanation of a phenomenon has to be transferred into the format of a presentation. But: As we are focusing on a specific medium, the digital presentation, and as it is so diverse in its modalities, it is important that we first of all clarify what exactly we mean by a digital presentation and what needs to be taken into account here.

As we already outlined: Progress in information technology enables a wide range of visualizations, for example, various types of graphics, dynamic or static, videos or photographs, which are not only useful for science communication in general, but also can enrich teaching and learning (Finkler & Leon, 2019; Hegarty, 2004). Against the background of this communicative scope of action, science communication and knowledge presentations are a field of multimodal argumentation. To go into detail about media possibilities in digital presentations, to fully outline them, is an impossible undertaking because, like all media, they are continually changing. Today, scientific data can be presented in a variety of ways.

3. MULTIMODALITIES IN SCIENCE PRESENTATIONS

Digital slide presentations make it possible to use a very wide range of communicative resources that no longer function purely as visual representations of lines of text but can transform the communication of knowledge into an audio-visual experience. Successful knowledge transfer and science communication through presentations results from the orchestration of different factors. This perspective which takes not only the technical- digital information into account but also all factors of the live scenario is widely used in media science and linguistics. According to the linguist Lobin, who asks about the textuality criteria of digital presentations, three modalities are crucial for presentation (Lobin, 2013). From a text linguistic point of view, the presentation in its entirety is created by coherence between the levels of impact. In order to create this linkage of all communication levels, the presenter uses his body language and voice. Another important factor is the spoken language, the verbal presented arguments. And finally, the visuals such the slides are important as well. These three modalities are embedded in a concrete knowledge communication situation, what requires an alignment of all modalities with the specific target group. The approach of distinguishing between three modalities in digital presentations is also shared by the media scientist Bucher (cf. Bucher & Niemann, 2012, p. 285). According to them the presentation has a complex structure. This complexity comes from the "paradoxical combination of two different patterns of discourse structure: a linear pattern in time – the sequential rhythm of the discourse – and a non-linear pattern in space – the constellations of signs and symbols in three- dimensional space"(Bucher & Niemann, 2012, p. 285). The theory of multimodal understanding asks about the processing methods of the recipients: making sense "means integrating different modes of communications systematically" (Bucher & Niemann, 2012, p. 302), which means that attention has to be distributed in time and space. According to Lobin (Lobin, 2007), coherence markers are not important within textual modality, but between modalities. The principle of coherence means that in one sequence all three levels must be brought into relation with each other. Each device on its own, but also taken together, produces rhetorical effect and has an impact on the audience (cf. Bucher & Niemann, 2012).

The findings of media studies that relate to the processing side can also be used for the production side perspective of rhetoric. Recognizing that information processing and attention allocation is a challenge for listeners means that the design of different modalities needs to be planned. Considering the rhetorical situation and the intended audience is central (Bitzer, 1968). In the case of knowledge and science communication, the wider public may include learners, citizens and people interested in science. Finally, the need to think about the rhetorical design of the different modes of presentation also concerns the level of argumentation, which in the case of digital presentations has a multimodal character.

Visual and verbal argumentation can be seen as "cognitive or logical operations", but the patterns of verbal and visual argumentation are different, for example because there is no grammar for visual information (Kjeldsen, 2015, p. 124). Its location at the level of cognition can be found in ancient ideas about perception. According to these, the addressee should be induced to imagine images which, in later cognitive processing, are indistinguishable from actual visual images. In Hippias' multimodal approach to rhetoric, it is irrelevant whether memories are generated through language or images (Koch & Schirren, 2016, p. 224f.).

Nevertheless, diagrams and similar material have an evidence-generating function in science communication (Kjeldsen, 2015, p. 125). This means that they have a knowledge-generating effect. At the same time, it cannot be assumed per se that the visual level of a PowerPoint presentation has an argumentative character. Rather, it depends on what exactly is shown visually, whether, for example, photographs or more abstract scientific forms of presentation are chosen (Kjeldsen, 2021). On the level of the rhetorical logos, diagrams and scientific representations produced with the elaborate means of graphic design can assume an important persuasive function. But it is precisely at this point that the constructive act of all rhetorical means is revealed: to make them visually accessible, which in some cases has resulted in elaborate data collection. They appear to be an objective image. At the same time, however, coloring, the choice of chart type, the presentation of bars, etc. are all means of emphasizing certain statements and persuading the reader to draw the desired conclusion (cf. Kjeldsen, 2021). Persuasion is therefore a matter of detail, and even representations that appear to be scientifically based can, like photographs, have a manipulative effect. However, graphic design techniques are particularly important for science communicators, especially in lay communication, to highlight key messages because their findings are particularly relevant to societal change and development. With regard to Ted Talks, which are not purely scientific events, Jiang & Lim talk about popularizing science, which refers to the 'engagement' factor of the communication (Jiang & Lim, 2022).

From our point of view, linguistic and visual means are each particular ways of organizing and representing knowledge. From our point of view, every representation is preceded by a constructive act of the orator. The orator decides in which way, for example, statistical values are visually presented. These statistical values are numbers, which therefore require interpretation. The orator decides which statement he wants to make. In rhetorical terms, graphic representation no longer encompasses only the objective level (logos) but is also sometimes aimed at pathos and ethos.

4. FOSTERING SKILLS IN MULTIMODAL PRESENTATIONS

Rhetorical, linguistic and media studies approaches are not sufficient for a theoretical approach to explanatory, knowledge-transmitting digital representations, because they do not sufficiently address the need for multimodal explanations that create meaning. They are also not sufficient for the development of students' presentation skills. We argue in this paper that findings from psychological and educational research are an interesting addition to the understanding of what other factors are important in the communication of knowledge. These insights can be used in the development of presentation skills to construct scientific explanations as a combination of verbal and visual information. At the Research Centre for Science Communication at the University of Tübingen, the Youth Presents team (Presentation Research Unit) is working on the question of how students can be encouraged to share their knowledge with others in presentations. The aim is to link research on the presentation of science with educational science work. Different disciplines will be combined in order to better support students during their school years. The following is an extension of the presentation approaches already outlined, and the question of what factors can be taken into account when promoting competence.

Inlearning contexts, linguistic formulationsare still important for comprehension, and anyone who has ever looked at complex scientific presentations without any background or prior knowledge knows that this must be a very condensed type of information, but that it is not easy to decode. Consequently, making knowledge communication multimodal is neither a simple solution nor an easy undertaking, since only a precise analysis of the communicative context provides clues for the rhetorical approach. This easy-to-understand perspective is the starting point for the development of presentation skills: students learn that multimodal communication of knowledge must start with its addressees. Youth presents has defined learning areas for students in relation to presenting: Rhetorical situation analysis, argumentation, language and structure, use of media, and body language and voice. There are strong links between all of these areas of learning, and none of them can exist on their own. Nevertheless, it is important to consider the different areas of action and presentation in isolation. The sequence makes it clear that the analysis of the situation must precede the concrete design of a multimodal argumentation.

Before we can understand the complex formal language of physics, we access physical facts e.g., via simple language and explanations. We also understand physics through concrete examples and observations. The principle of concreteness fading is known from instructional psychology (Fyfe et al., 2014). This means that concrete materials are very important at the beginning of learning, and we would add in expert- layperson communication. In expert communication, on the other hand, the degree of abstractness can be high. The generation of evidentia and the choice of rhetorical devices depend on the level of knowledge of the learners. For the presentation in the school context, this means that students need to be aware of their acquired knowledge and also recognize where their addressees may have even less knowledge. Even if this is not a situation of expert-layperson communication in the strict sense, it can be said that any additional knowledge acquired may already require explanation to outsiders. Detailing (in terms of language, visualization) might be a good approach from a rhetorical perspective. However, this seems to be an important area of learning for students, as research has shown. For it is precisely the additional information in an explanation that can make it easier for the listener to understand that is sometimes missing from students' explanations. Instead of the rhetorically necessary strategy of enárgeia, they follow the rhetorical principle of brevitas (Lipphardt, 2019, p. 138f.). The fact that paraphrasing and finding words seems to be a challenge is also often seen in presentations, for example when slides are just shown without explanation.

The promotion of competencies should lead to a reflexive use of rhetorical means and to a differentiated view of the format of digital knowledge presentation, because even strategies such as enárgeia have their limits, as we know from cognitive psychology research. One refers then to the seductive detail effect (Sundararajan & Adesope, 2020).

Therefore, it makes sense to focus on the different modalities with students and to work on consciously shaping them. However, developing competence also involves linking all the means of communication.

5. AN EXAMPLE FROM THE FIELD

What could such a presentation look like, covering the aspects mentioned in our paper? In which the different modes of a digital presentation are used - text, visualizations, (moving) images? A presentation that shows how useful a path diagram can be for identifying and breaking down arguments? To answer this question, we will analyse a video example of a student's presentation from and for Youth presents (Wie Kommt Es Zum Gigantismus Bei Insekten?, 2019) – which is meant to explain a complex matter to students of the same age.

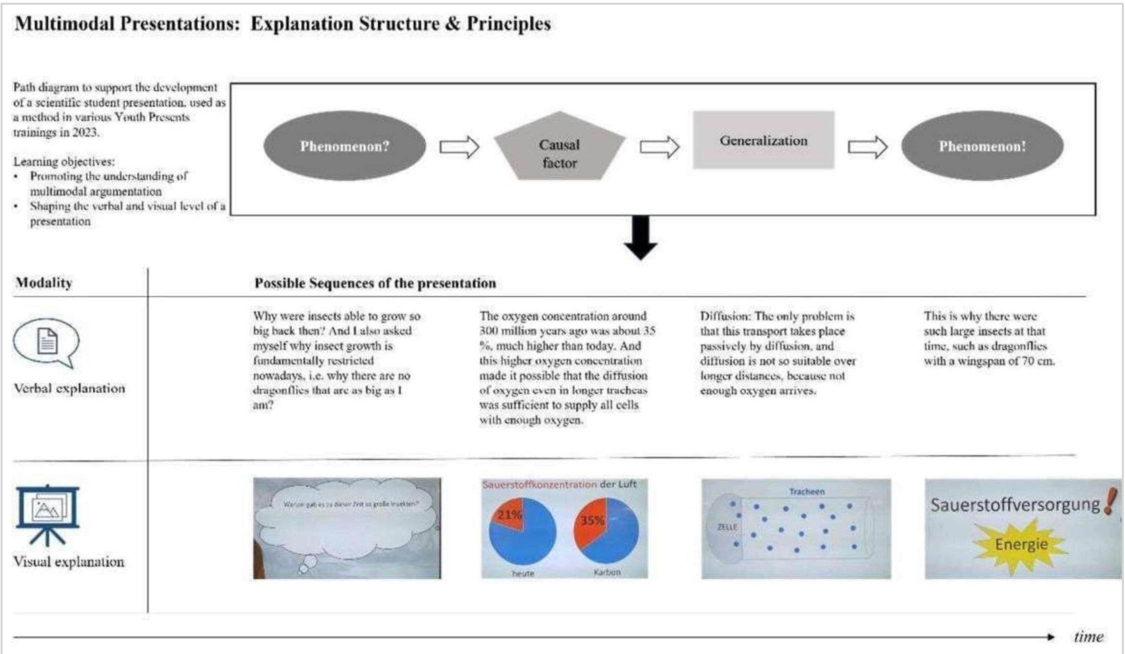

Figure 2: The path diagram applied to a presentation of Youth presents (own representation of authors)

Although this is an analysis, i.e. it is necessarily done from the point of view of the recipient, the analysis should refer to the rhetorical point of view of the producer, i.e. how the producer of a presentation can act and use the possibilities of digital presentation to convey knowledge.

What we can see in the presentation are various visual and verbal methods that make it easier for classmates to understand the content. The student has taken into account the audience's prior knowledge: She seems to have assumed in her preparation that her addressees do not yet have much of an idea of the subject, which is evident from the richness of detail in her explanations (concreteness). For example: She does not ignore the different breathing patterns of humans and dragonflies but explains them in a nuanced way. It is, so to say, an easy-to-understand perspective. She also provides a question that allows her to address several biological, physical processes, such as diffusion, pulmonary respiration, tracheal respiration, and explain them with illustrative (evidentia) examples.

Furthermore, and with reference to the path diagram we explained above, addressees can follow her presentation not only because she goes into the complex knowledge content in a concrete and vivid way, but also because she provides orientation with the guiding question verbalized at the beginning. She refers to this guiding question by continually addressing it, and in the end the attention of the addressees is "rewarded" by receiving a clear and comprehensible answer to the question (see Figure 2). This example can be used to analyze it with pupils, explain the path diagram to them and show the benefits of it.

6. CONCLUSION

In our remarks, we have shown that digital presentations are a special format of science communication. Depending on its situational embedding, it requires the communicator to choose special rhetorical means in order to answer the central question in a way that is comprehensible to the addressees. Knowledge and science communication is thus a constructive act of the communicator. The rhetorical construction of a response involves the elaboration of a multimodal argument. The spectrum of visual, verbal, and audiovisual forms of knowledge has become clear - and also that it is always a sign of the times, i.e. of media development and data generation. But it is precisely this diversity that represents a hurdle in the communication of knowledge. Exceptional research does not automatically lead to exceptional communication. This is why it is so important to develop students' presentation skills early on.

Youth presents has many years of experience in developing practice approaches to improve presenting in students. The content-related examination of a topic, which must inevitably precede every presentation, ideally leads to the conception of a multimodal argumentation. One way to practice this with students is to use a path diagram to consider specifically what is conveyed visually and what is conveyed verbally. This enhances the presenter's understanding and can also lead to providing better explanations in the presentation situation.

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