POTSDAM-INSTITUT FÜR KLIMAFOLGENFORSCHUNG

Climate Impacts for German Schools – an Educational Web Portal Solution

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Abstract

Climate change education is one of the integral components within the global Education for Sustainable Development (ESD) initiative by the United Nations. However, it is not trivial to bridge the gap between complex scientific information and the requirements of education. Now the educational portal www.KlimafolgenOnline-Bildung.de offers a solution by preparing scientific knowledge about climate impacts in Germany for interdisciplinary use in schools. Tailored climate science fundamentals and background information were provided to help teachers and students to develop an understanding of the complex relationships of climate change in different sectors like climate, agriculture and forestry. The strength of this solution lies in its direct regional reference, and the option to interactively explore scientific climate data. It raises awareness for immediate effects of climate change on the individual living environment.

This paper outlines the development process for the web portal, and the lessons learned. The underlying development process was based on workshops and surveys with teachers. Teaching material was developed to integrate climate change knowledge into school lessons, such as background information on data uncertainties and scenarios. As one of the results in six “research workshops” conducted students can now explore, compare and discuss climate change impacts in different sectors as well as suitable adaptation measures.

Introduction

Today`s information- and knowledge-based society requires a direct dialogue between society and science (Schäfer et al. 2015). Through the internet, information is constantly available. However, it is only an individual who can demand, understand and evaluate it. The evaluation of information and messages is difficult. On one hand, the immense abundance of information

through the new media formats can lead to disorientation and cognitive overload; on the other hand, information is sometimes obsolete, torn out of context, or simply wrong.

In dealing with the complexity of the available information, education plays a central role. For this reason, modern education in schools is competence-oriented, in other words, directed at everyday life. Students should be empowered to use information so that they can ultimately make reasoned decisions (Heymann 2004). Education must therefore always be re-calibrated.

In the specific case of climate change communication, various studies indicate that temporal and spatial distance is a barrier to the communication of climate change (Stoknes 2014; Pidgeon and Fischhoff 2011). As people perceive climate change as a phenomenon that takes place far away and in the future, they feel the issue of climate change less relevant than other current things (Raymond and Brown 2011). Teaching the aspects of climate change always means that teachers have to relate to the fundamentals of the subject. This is the only way for students to acquire the necessary competencies to orient themselves independently and to reflect on their own actions.

In practice however, there is a lack of methodological support, specialized material as well as suggestions on how to address complex scientific topics. In addition to the education and training of teachers, new insights into climate change are often not considered sufficiently. Teachers are on their own usually determining how to fill this gap and respond to urgent questions from students. For non-specialists it is a challenge to understand the complex subject of climate change. In addition, many of the current relevant research results remain hidden from the eyes of the layperson.

To enable teachers to better explain the complex relationship of climate change, its impacts on the society and available adaptation options, the educational online portal www.KlimafolgenOnline-Bildung.de was developed. It illustrates these effects in the case of Germany and provides first-hand research. This gives teachers and students the opportunity to explore scientific data on climate change down to the county level, which creates a strong regional connection. The rationale behind is to make the portal particularly interesting and practice-orientated, because the consequences of climate change can be reconstructed for the personal living environment.

The new educational web portal www.KlimafolgenOnline-Bildung.de is based on an existing tool (KlimafolgenOnline.com) which was launched in 2012 and developed for public sector decision makers to show the impacts of climate change in Germany. The new educational portal was designed by applying feedback from more than 40 teacher workshops. The findings were incorporated into a less technical, more self-explanatory, tailored solution for the use in German schools. Finally, it was evaluated by teacher workshops and a survey.

In order to use the portal and the learning modules correctly, teachers were trained in advanced training. Additionally, handouts, explanations and a tutorial were made available. Also, accompanying teaching materials were developed, which were tested and improved upon over the course of the project period. A total of 16 learning modules have been developed for interdisciplinary use in which the ecological and economic impacts of climate change are presented, for example, for agriculture, forestry, winter tourism and health. The “research workshops” (Lehrer-Online 2016), for example, help students to derive reasoned decisions for adaptation measures for different areas of life on the basis of the data organized in sectors.

However, the development and use of such a platform for teachers comes with a number of challenges that will be discussed in the course of this paper. First of all, scientific literature criticizes the lack of effectiveness of many existing climate impact platforms that do not account for the specific needs and characteristics of their target groups (Mitchel et al. 2016). To allow accessibility for students with different previous knowledge, experiences and capabilities, web portals by themselves also require a high level of plasticity (Walber 2005). Further challenges include the handling of scientific terminology and scientific visualizations for non-expert users, the communication of uncertainties and the integration of interactive web portals in school lessons in general.

The following paper provides a background of the developed solution (sec. 2), describes the methodology (sec. 3), the teachers` feedback from the workshops (sec. 4), the design and implementation process (sec. 5), the discussion and lessons we learned from and with teachers (sec. 6), and finally a conclusion and outlook (sec. 7).

Background

Web-based geo-platforms enjoy great popularity in the field of climate change communication and public engagement with science in general (Neset et al. 2016).The experiences gathered in the PIKee-project and literature on similar projects have shown that web portals provide great opportunities to present results of climate research processes and make it more tangible at the local level.

Web portals are also a great medium for conveying **media skills** within the curriculum.
As media competencies are an integral part of the school subjects its methods are used in interdisciplinary projects to develop professional, social, methodical and media relevant competencies. For example, media pedagogy also contributes to the profiling of school concepts. At school, the focus is on the assessment of the media, the recognition and processing of media production and influence, the selection and use of media offerings and the design and distribution of own media products.

In Germany, the federal states are responsible for **education**. This means that the ministries of education of the 16 countries decide about the curricula. The development of curricula is a slow process. Therefore, in practice, there is often a large gap between current events and the school curriculum. A good example is the new curriculum of Berlin and Brandenburg, which was commissioned during the school year of 2011/12 to be implemented in 2017/18 (Bildungsserver Berlin-Brandenburg).

In 2007 a review of the "Orientation framework for the learning area of global development in the context of **education for sustainable development**" (Siege and Schreiber 2015; United Nations 2016) provided federal states in Germany with a basis for the development of curricula and to offer concrete recommendations for the inclusion of topics such as sustainable and global development. According to the guidelines of the federal states, there are references to various aspects of climate change in several subjects and for all age levels, from primary school to upper secondary level. Nevertheless, the implementation of the subjects ultimately depends in many cases on the personal commitment of teachers. In this context, the idea emerged of using the origins portal's potential for use in German schools.

Illustrating the foundation of this paper, Figure 1 left depicts the user interface of the original web portal. Located on the top (left-hand side) are the symbols representing the sectors for which data is provided: climate, agriculture, forestry, water, energy and miscellaneous. Each sector is associated with a bunch of parameters representing sector-specific data. For example, for the sector climate these are daily maximum temperature, precipitation or number of ice days, to name just a few. Once a specific sector is selected, the associated parameters appear along the top and more as part of a drop down-menu. In the navigation window on the right hand-side the user can choose between the displayed average periods (30 yearly as the standard), seasonal visualizations, the Representative Concentration Pathways (RCP) scenarios, selected climate model runs and topographic navigational elements. At the bottom, a specific period in time can be chosen from the time scale to display the map data.

Figure 1 on the left also provides a first impression of the shortcomings of the graphical user interface design of the original portal. The small info box on the left-hand side has proved too small to truly aid orientation. The color legend on the bottom left-hand side can be easily overlooked. Also, the original portal offered two separate helping systems (one can be activated by the bottom left-hand side (‘i’) and the other by the top (‘?’)). This has been a constant cause for confusion as users found it hard to find the information they required.

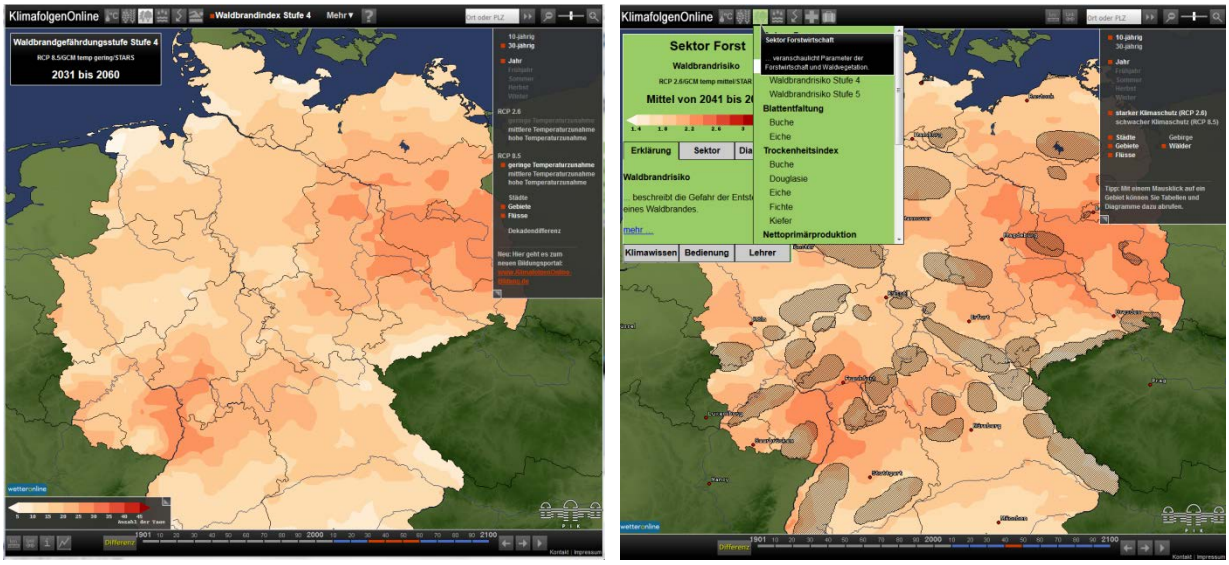

Figure 1: Screenshot of original climate impact tool with 30 year average as the standard setting (left); Screenshot of the redesigned education version www.KlimafolgenOnline-Bildung.de with 10 year average as the standard setting, presenting the new info box and colored pull-down menu (right)

In contrast, Figure 1 right provides a first glimpse of the new, educational version www.KlimafolgenOnline-Bildung.de. Some of the new design elements are immediately noticeable. In the following sections, we will describe the process of its design and implementation.

Methodology

For the design and development of an educational climate impact web portal solution the following rationales were applied:

- Reducing entry barriers into the complex climate science topic for teacher and students

    - by reducing the complexity of climate science information (graphical user interface, terms, visualizations), evaluating simplified material by climate scientists
    - by developing multiple complexity levels for learning lessons for different classes and subjects
    - by developing easy-to-use learning units and tailored climate science background information
- Having intense practical seminars with trainee teachers
    - to test the interdisciplinary applicability of the original portal
    - to co-develop prototypic teaching units
- Conducting multiple workshops with teachers in several federal states
    - to test the applicability in heterogeneous curricula and to get feedback
    - to achieve a multiplier effect
- Strongly interlacing the individual process steps
    - to ensure a match between the design of the platform and the needs of teachers and students
    - to get immediate feedback loops
- Injecting impulses into climate (impact) science about the requirements in educational climate communication.

Based on this rationale the education portal development was designed using the following workflow:

1. *Curriculum/original portal analysis included:*
    - Identification where the relevance of the topic fits to the needs of the existing curricula, including sustainable development (desktop analysis and stake holder discussions)
    - Investigation into applicability for which subjects the original portal (Fig. 1 left) can be used, identifying first ideas for teaching units (four seminars of teacher trainings were held)

2. Workshops with teachers
- Execution of workshops and interviews with teachers, students and environmental educators
- Evaluation of the original platform and incorporating their feedback about the usability in terms of the interface, the design and background information for the development of the educational version.

3. Portal improvement / development of learning material & guidelines
- Redesign of the user interface and the scientific content to improve understanding for non-expert audiences.
- Development of data explanation and background information on scientific topics addressed by the platform
- Elaboration of teaching modules providing structure and ideas for the usage of the platform in class (accounting for the institutional setting of the German educational system (curricula))
- Creation of a tutorial

4. Validation workshops
- Evaluation of the platform in workshops with teachers
- Implementation of adaptation measures and incorporation of feedback.

To get a first impression of the usability of the original tool in schools, a desktop analysis of the general potential was performed and (pre-) tested with teachers and trainees. Building on these experiences, the development of the educational version has been set out as an intertwined process entailing intense trainee seminars, user evaluations with about 800 teachers, an adaptation and preparation part of scientific content, a redesign of the graphic user interface (GUI, see Fig. 1, right), and the elaboration of didactic material. The results of the teacher feedback sessions were collected and categorized. The most essential feedbacks were selected, evaluated and implemented.

Teacher workshops and feedback analysis

In the first step, we conducted a desktop analysis of the general potential of map based climate impact web portals, which included the examination of relevant topics in different curricula. We found a broad field of potential interdisciplinary applications in school subjects: besides geography we identified biology, mathematics, English, German, philosophy, physics, computer science and others. In a second step we developed concrete ideas with trainees for concrete learning units.

In the third step, teachers were introduced into the original web portal solution, evaluated it and provided feedback in two formats: a survey and a discussion. In the survey, we asked about the applicability in teaching with an interdisciplinary perspective for their requirements about how to make it usable for teaching climate change impacts. We classified the feedback into three categories: portal design & graphical user interface changes, content changes including the data visualizations (maps & time series plot), portal content explanations and background related texts and videos, and missing issues and additional requirements. The feedback was analyzed and prioritized according to must-haves and nice-to-haves. Major results are summarized in Table 1.

One of the limitations was the design of the original user interface. Teachers suggested to reduce its overall complexity by simplifying the portal structure in general and to provide improved orientation and helping systems to cope with the complex information space of sectors, parameters, scenarios and time periods. In this context they asked for the provision of an introductory element to the portal, which would describe the sectors and the possible settings. Further they suggested to reduce duplicate functionalities (two types of helping systems) and to re-order menu items. Teachers requested to re-organize the parameter selection lists, to reduce the multitude of presented climate scenarios and to simplify legends.

Table 1: Collected demands from the workshops, ordered by their importance (bold: implemented, plain: not implemented, cursive: implementation not possible due to technical or financial hurdles)

Portal design & graphical user interface	**Content**	**Additional requirements**

• **Front page with introduction for using the portal** • **Reduction of duplications and reorder of menu items** • **Reduction of user interface complexities (e.g. two helping systems)** • **Simplification of the multitude of climate scenarios** • **Improvement of clarity in the representation of parameters**	• **Integration of tutorials for using the entire portal and understand the complexities** • **Reduction / simplification of scientific vocabulary** • **Improvement of parameter and sector background description** • **Clarification and simplification of parameter explanation and contextual information texts** • **Improvement of scenario explanation** • *Simplified interpretation of diagrams/graphics, including labels for the axis*	• *Development of several variants tailored for different grades, forms of schools and teachings* • *Usability for touch devices (smart phones, tablets and white boards)* • *Comparison with climate change impacts in other countries; data beyond Germany's border* • **Extraction of maps for further use on white boards** • Additional topographic information, urban centers, industrial regions**, forest or mountain layers** • **Comparison of two maps / tables** • *Explicit interpretation of the spatial distribution and temporal trends of all physical parameters (e.g.: What are the consequences of more swimming days?)* • *Option for collaborative exchange between teachers and students (e.g. portal blog)*

Plenty of feedback was gathered in regard to the **content of the web portal**. The main concern in this context was a clearer overall communication of the climate change message and the complex interrelationships. While the portal has a good data basis, the explanation of this data was conceived as too complicated, and a reduction of the scientific language was identified as a pressing issue. In particular, the teachers requested a better explanation of the meaning of physical parameters and their statistical aggregations, a clarification and extension of background information, for instance additional sector information, an improved explanation of the climate scenarios and climate model uncertainty explanations. Further, the teachers suggested to use tutorials as an explanatory element within the portal, and asked for a simplified and alphabetically organized glossary.

Additional requirements of teachers were syntactical and semantical description of the maps and diagrams and labels for axes. An interesting feedback was that different variants of complexity for varying forms of schools, grade levels and teaching methods could strongly reduce the entrance barriers for younger students and teachers. To compare different visualizations or time periods directly, a portal side-by-side image comparison option was a further feature request. Some of these suggestions could not be realized due to budget constraints, but it was possible to offer some workaround options: users can make screenshots or open an additional browser window for the cross-examination of individual maps.

Beyond the web-portal related feedback, more general **questions** related to climate change communication in schools were raised by teachers, including the following:

1. Where can information on climate change be found?
2. Which climate changes can be observed already today?
3. How certain are projections about climate change?
4. How can personal references to climate change be established?
5. How can options for action be shown?

Design and implementation of the education portal www.KlimafolgenOnline-Bildung.de

The most essential suggestions from the teacher's workshops were implemented into the new educational portal. The reduction of complexity took place on two levels: graphical user interface re-design and its implementation by WetterOnline and the adaptation and extension of the portal content including the integration of new media types. Due to convey and workshops it became apparent that most of the parameters of the original portal were interesting for the use in school. Particularly exciting, among others were the parameters presented in "miscellaneous" that shows indicator variables for the areas of health and tourism. It was therefore decided to show their parameters individually in the "health" and "tourism" sectors.

The Graphical user interface was re-designed by adding **(1)** a new orientation info box that integrates an overview of currently selected sector, parameter, model chain, time period, color legend with short explanations (Fig. 2 center). It provides entrance points to the **(2)** new hierarchically structured helping system (Fig. 2 left). The parameters within the portal have been organized by sectors and by topics (Fig. 2 center, right).

Users can now find all the parameters color coordinated (see Fig. 3) and organized in drop-down menus underneath their respective sectors (Fig. top right). Each selected parameter is shortly explained in a new info box on the left hand side, which also improves the overall navigation of the portal (Fig. 2 center, Fig. 3). In addition, we reduced the portal complexity in comparison to the original portal by now showing the median of the global climate models only. (Fig.2 right).

Following the teachers' feedback on the **content** side, the overall vocabulary of the portal was adapted to the educational requirements in secondary levels 1 and 2. Scientific terminology was reduced to enable an easier access to the topic of climate change impacts. For instance, the RCPs have been re-named as representing "weak climate protection" and "strong climate protection" in order to better communicate their meaning and increase understanding among users. This reduction process was done with tight incorporation of the domain scientists.

In order to cope with the uncertainties of future climate projections, further complexities of climate science, and the challenges these induce for school lessons, various textual teaching material and background information were conducted. The simplified and alphabetically organized glossary aids to understand the subject and explanations.

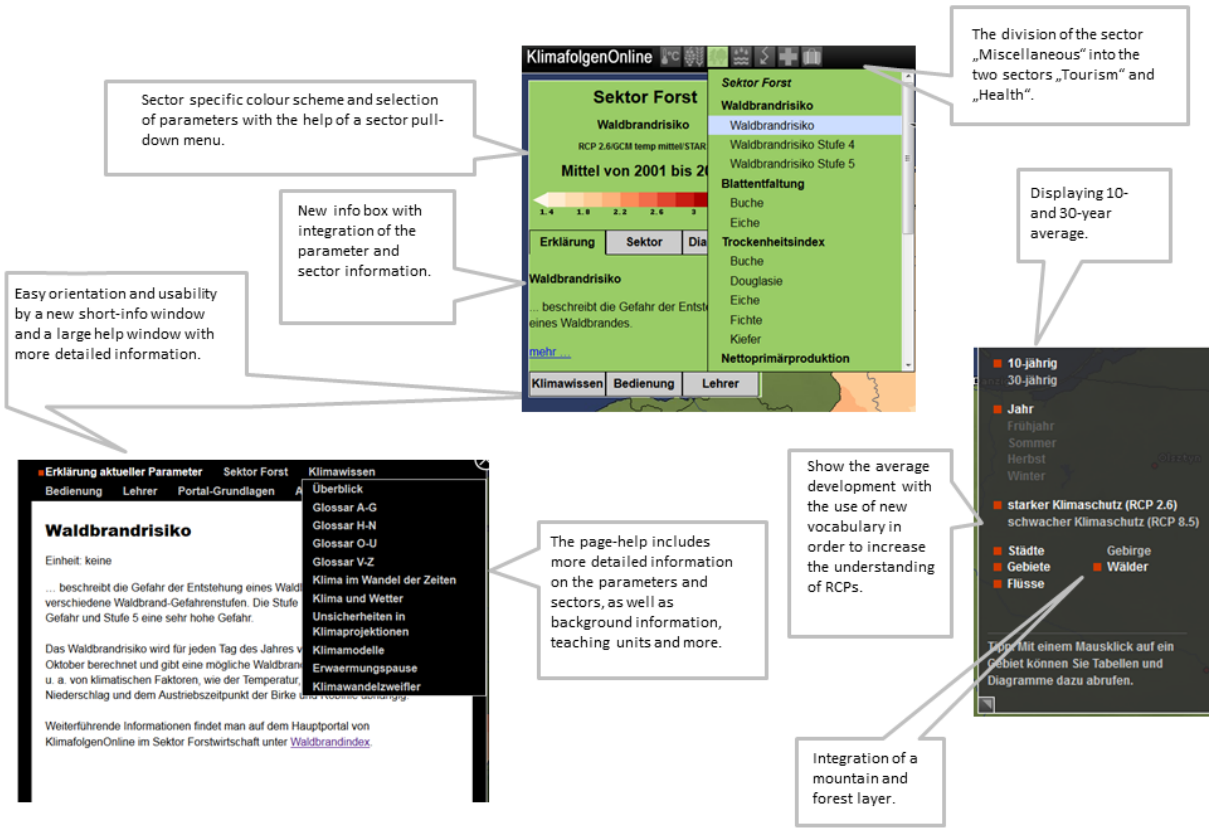

Figure 2: Presentation of the improvements on www.KlimafolgenOnline-Bildung.de presenting new hierarchically structured helping system (left); color-orientated info box integrating an overview of selected sector, parameter, model chain, time period

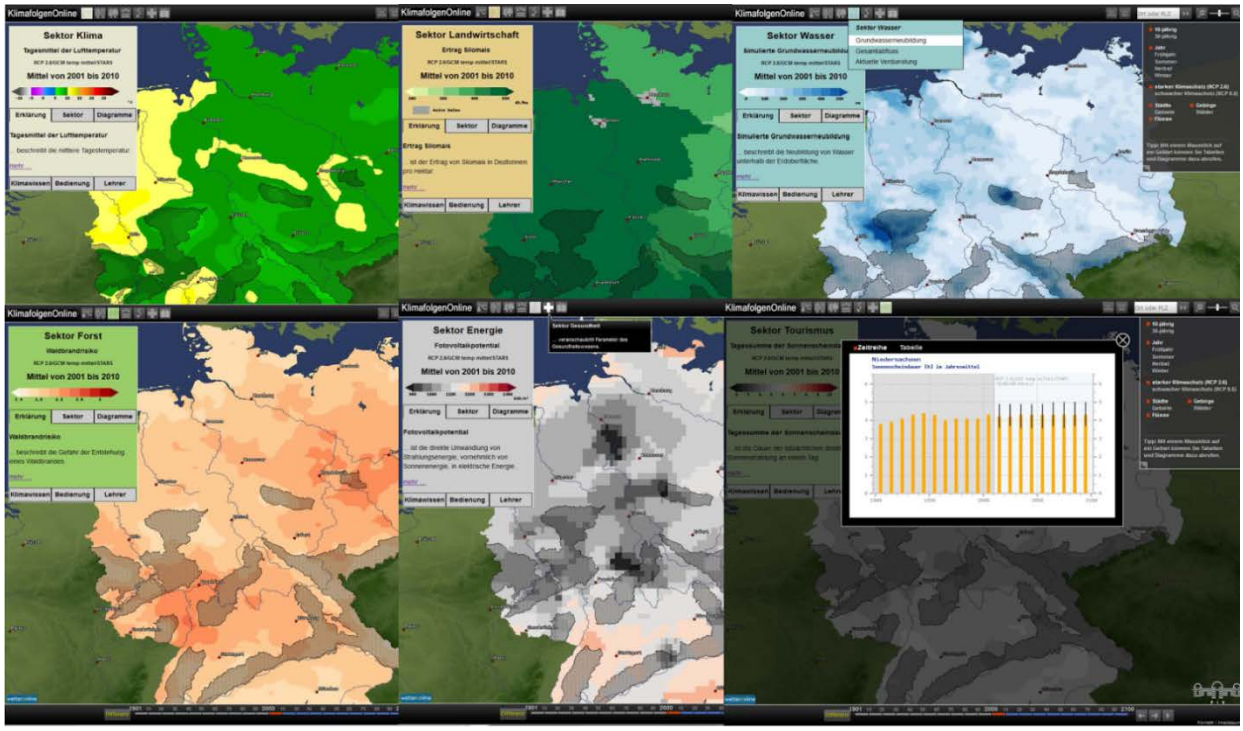

Figure 3: Example for the color coordination of a selection of sectors (left); the drop-down menu for the sector water (top right); an example of a diagram within the sector tourism (bottom right)

To provide an overview of the most important functions and how to navigate the portal, a tutorial (YouToube) was created using an animated introduction video. This tutorial is intended to help all user groups to easier access the functions and contents of the portal. Furthermore, to provide answers to the general questions raised during the workshops (see previous section), we developed a general guidance (Blumenthal et al. 2016) how to deal with certain aspects of climate change communication. This guide is designed to encourage teachers of all disciplines communicating climate change and its effects without being an expert. There are hints where information can be obtained at different points and how best to communicate them.

In order to support teachers in using the portal a variety of 16 teaching units were developed. The six "research workshops" were designed for individual sectors and are available in three different levels of difficulty. These levels may apply to different school or competence levels among students. Teachers can choose the one appropriate for their students' abilities. The "research workshops" can either be used during regular lessons or within interdisciplinary project work. Other teaching units are subject-specific. They have been designed for geography, but also for natural science subjects, mathematics or English lessons. All of the teaching units are presented within a dossier on the teacher's portal Lehrer-Online (Dossier) and freely available.

Discussion and lessons learned

The goal of developing the new educational portal www.KlimafolgenOnline-Bildung.de was to reduce the accessibility barriers by teachers and students. The workshops with teachers uncovered a number of challenges that teachers face in implementing digital media in their lessons. These workshops draw attention to the teachers' uncertainness of working with scientific information, existing limitations in scientific understanding and media competence. Climate denialists` arguments were also raised by the participants. Either teachers brought up the subject because they had doubts or they asked how to handle requests from the students.

Throughout the course of the development process the **gap between teachers and students** in regards to computer and media skills has become apparent. This gap has been pointed out by the teaching staff themselves, who recognized that so-called "digital native" students, who grew up with digital media, have an easier experience navigating the portal than teachers. The generational gap between 'digital natives' and 'digital immigrants' was particularly pronounced during a mixed feedback round attending students and teachers. While the students were adequately informed by the portal's tutorial and had figured out its functions by clicking their way through, the teachers expressed the wish for a day long workshop introducing the portal, its functions and potential uses. In connection with this observation is the issue of teachers showing a lack of confidence in front of their learners. The large gap in experience with digital media between students and teachers puts the latter in a position that only inhibits their confidence.

Teaching staff usually is under time pressure when preparing high quality lessons. **Time management** was an issue mentioned by teachers on many occasions as one of the reasons they shy away from using new media they are not confident in using. This especially applies to a portal communicating a scientific topic with an abundance of data, which is in some cases still controversial. Teachers may easily feel overwhelmed given their limited time availability. Another concern by teachers was the low **level of attention span** of some students. They also mentioned that students can easily get bored when they cannot find the information they need

and thus cannot advance in solving their task. The platform www.KlimafolgenOnline-Bildung.de offers a range of sectors and parameters, which students may feel tempted to explore. Additionally, some of the teaching units offered with the portal require the students to use external websites to gather supplementary information.

Teachers have repeatedly described how students showed difficulty in understanding the **practical applicability of the lessons** learned within school. They tend to understand the content of their lessons as something that needs to be remembered for the next test, but see no practical use for it beyond school. Working with a portal like www.KlimafolgenOnline-Bildung.de, on the other hand, offers the chance to make that connection to the world beyond the classroom and illustrates that the knowledge conveyed within the lesson is of lifelong use and may well be applicable for the students' future careers. It also illustrates that the subject of climate change is no schoolbook theory, but one of the greatest challenges of our time, also in Germany, that an entire scientific field is dedicated towards solving.

Breaking down the science and **bridging the gap to the educational** sector was one of the biggest challenges. In order to communicate the science behind climate change and the most relevant topics within the climate science, background information was provided within the original portal. The aim was to keep the scientific truths, but to make it accessible for a young audience. This required the adaptation of large parts of the original portal's content and some of those have already been pointed out above, like the re-naming of the used RCPs or the use of the 10 year average as the standard setting in visualizing climate change. While in climate science the 30 time span is used for this purpose, time spans of this extent may overwhelm in the educational context. They may move the subject of climate change beyond students' conceivable imagination. This defeats the purpose of a portal designed to visualize that climate change is happening in the here and now.

The **challenge of complexity of terminology** is closely linked to the issue of target audiences. As the work with the original portal with teachers has shown, particular user groups require different degrees of information complexity. Moreover, these groups use different terminologies to express the same scientific facts and concepts. While experts in hydrology or agriculture would ask for high resolution data and to download datasets, lay people would require a translation of scientific facts into everyday language. A focus on adaptation challenges through the use of two climate scenarios is a good example for this. It clarifies the increase in challenges with every degree of global warming and draws attention towards the practical consequences of climate change.

To simplify the complex subject of climate change, glossary, tutorial and an easily accessible data explanation are using a lay person's language. Similarly, the tooltips give an easy to understand overview of the portal's elements and help the user to navigate. One of teachers´ most favorite improvements is the reduction in parameters and their re-organization into sectoral categories. This re-structuring also helps to make the subject more accessible and aids an organized approach by the user.

Conclusion and outlook

Within this paper, experiences and insights in designing and using an educational climate web platform in school lessons were presented. First of all, the new solution proved to be beneficial in closing the gap between the perceived spatial and psychological distance to local climate change impacts. The inclusion of users on teachers and students has made it possible

to provide tailor-made information, taking into account specific objectives, practices and institutional attitudes in the German education system.

The re-designed portal enables teachers to use a digital medium in the classroom by providing comprehensive information and additional support in teaching climate change. At the same time conveying of media competencies facilitates a self-evident use within the curriculum. Teachers have confirmed the interdisciplinary usability of the educational web portal, even though some barriers remain in the utilization of digital media within the school context and lack of knowledge about climate change. In order to reduce these barriers in terms of time management and media competence, it needs well-prepared material with little preparation time for the teacher. Furthermore, teachers should be given continuous training. For bridging attention span problems smaller-scale approaches will be developed in the future.

In summary, the educational portal www.KlimafolgenOnline-Bildung.de opens the door to a complex topic such as climate science. While many efforts of outreach have already been done by climate science, teachers have reported that it is still perceived as very detached. Thus, they welcome the opportunity to show students the topicality and practical appliance of the curricula with the help of the new web portal www.KlimafolgenOnline-Bildung.de.

For future work, the implementation of further suggestions from the teacher feedback, and a extension for students in vocational schools is planned. This will include a further reduction of complexity and a bunch of small teaching units, which will be guided by animated tutorials. Then we expect to inspire even more teachers using the portal in school.

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Biographical notes

Ines Blumenthal is project manager of the PIKee environmental education project at the Potsdam Institute for Climate Research. She is an educator, media designer and a parent media consultant. Before she joined the Potsdam Institute in 2012 she worked 12 years for various clients and created project-related target-oriented concepts and products for textual and visual communication.

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Simon Hirsbrunner is a Ph.D. candidate in Science & Technology Studies at the Research Training Group *Locating Media*, University of Siegen. In his research, he focuses on the mediation of climate change futures, on visual science communication and on maps. Prior, he has been a consultant and researcher in climate change communication at a German think tank. In Berlin, he co-founded the mapping lab Deixis, which experiments with and develops map- and location-based applications.

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Thomas Nocke is senior researcher at the Potsdam Institute for Climate Impact Research, with a Ph.D. in Computer Science, University of Rostock. Since 2002, he has been investigating the topic of climate data visualization, both for visual data analysis and visual climate change communication. Since 2012, he manages the developments of the portals KlimafolgenOnline.com / ClimateImpactsOnline.com (as lead of the ClimateKIC project CIES), as well supporting the new educational version KlimafolgenOnline-Bildung.de. His research topics include environmental visual analytics and innovative climate service solutions.