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Students' Preconceptions of the Formation and Location of Deserts: Results of a Qualitative Interview Study with Grade 7 Students in Germany

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Abstract

In the educational learning process preconceptions are an important factor. Learners usually interpret new input on the basis of their own preconceptions that are the result of various experiences made before being confronted with the educational learning process. Hence, the investigation of preconceptions is a main task for educational research. This study examines the preconceptions of thirteen grade 7 students (ages 12 and 13 years) on the topics "formation and location of deserts." Semi-structured and problem-centered interviews were used to collect the students' preconceptions. The following analysis was based on qualitative content analysis methods. Regarding the formation of deserts, four basic preconceptions were identified, e.g., "Wind amasses sand with the result that a desert forms." All four preconceptions have two characteristics in common: the origin of sand is simultaneously their basic concept and a problem of comprehension when thinking about the formation of a desert. Additionally, in the students' imagination all deserts are sand deserts. Concerning the location of deserts it can be stated that "heat" and "dryness" are the main factors, which are used when explaining the location. At the same time, the students seem to have no basic spatial grids and orientation systems concerning the location of deserts in the world that corresponds to scientific conceptions.

Keywords: preconceptions, desert formation, desert location, qualitative interview study

Introduction

Inquiry Learning as stated in the National Science Education Standards (National Research Council, 1996) defines the acquisition of knowledge as an active process during which conceptions are developed, modified or re-organized (Anderson, 2007). Students' preconceptions are a vital element in the learning process as they are the premises and thus starting points for learning as well as potential hurdles in the learning

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process (Beck & Krapp, 2001; Duit, 2006; Reinfried, 2007). Preconceptions are the result of situations students have experienced before being confronted with the educational processes of learning. Thus, learning is a process of active construction on the basis of already existing preconceptions (Duit, 1995). Everything a student perceives is interpreted depending on the student's previous knowledge and his/her pre-established beliefs (Gerstenmaier & Mandl, 1995). In this context, student conceptions (Confrey, 1990) are conceived as individual cognitive constructions (Gropengießer, 2007), which can neither be transmitted by the teacher nor taken up by students for they are individual, active constructs (Confrey, 1990; Reinmann & Mandl 2006; Riemeier, 2007). This empirical study focuses on those conceptions students already have before receiving instruction on deserts. Thus, in this study conceptions are always understood as preconceptions (Möller, 1999).

The investigation of students' varying conceptions is one of the central tasks of educational research in science as well as in the field of earth science (Lethmate, 2007; Reinfried, 2007). Nevertheless, the overall current state of research in geography concerning students' preconceptions is still quite low (Duit, 2009; Reinfried & Schuler 2009). There are empirical findings on some geographic topics such as earthquakes, volcanoes, world grid, sea level, landforms, weathering and erosion and soil (Burton, Robert, & Francek, 1992; Dove, 1998), groundwater (Dickerson & Dawkins, 2004; Reinfried, 2006), global warming (Boyes, Skamp, & Stanisstreet, 2009; Meadows & Wiesenmayer, 1999), and greenhouse effect (Boyes & Stanisstreet, 1993; Reinfried, Aeschbacher, & Rottermann, 2012; Schuler, 2011). While "deserts" are a central topic in geography from grade 7 to grade 9 in Germany and can be linked to the benchmarks published by the American Association for the Advancement of Science (AAAS, 1993) and the National Science Education Standards (NRC, 1996), the only studies that provide initial insights by eliciting students' associations are Adamina (2008) and Dove (1999).

In the first study, 70 bachelor degree students in England were asked for their associations of deserts (Dove, 1999). The terms most mentioned as associated with deserts were "sand" and "dunes." "Palms," "oases" and "camels" were also stated, as well as – to a lesser extent – "cacti," "tents" and "pyramids" (Dove, 1999). In addition to their associations, the students were asked to sort different desert pictures according to the degree of conformity with their respective conception. The desert picture showing sand and dunes was selected most often. Since, in addition, the Sahara desert was most frequently mentioned when asked about known desert names, Dove speaks of the "Saharan stereotype." Dove claims that this Saharan stereotype dominates conceptions of deserts.

In the second study associative techniques were also used. One hundred and thirty-four German-speaking students (grades 3, 5 and 7) were asked about their associations of foreign spaces, one sub-section referred to their conceptions of deserts (Adamina 2008). The results are similar to the ones in Dove's study. "Sand" and "sand desert" are the most often mentioned terms and the Sahara Desert as the only desert name mentioned (Adamina, 2008). Other frequently named terms are "hot" or "sunny" and

"dromedaries" or "camels." It is notable that similar results were found in grades 3, 5 and 7 (Adamina, 2008).

Overall, both studies provide initial important insights of student's conceptions of deserts. Considering the methodological approach by working with associative techniques, the identified conceptions remain on a low level of complexity (Gropengießer, 2007). That implies the relations between the terms used by the students are unknown as well as explanatory processes and causes. Those can not be identified with associative techniques. All in all, insights in thought structures in their depth are missing. Concerning the contents the studies' results give insights on what a desert is from the students' point of view. However, there is no evidence for conceptions on other desert-topics, e.g. on how deserts form and where deserts are located.

Against the background of both the high relevance of deserts as a central topic of geography education and the lack of differentiation in the current state of research, the presented research project explores students' complex preconceptions about the "formation and location of deserts". The project is part of a thematically broadly conceived research project (cf. Schubert, 2012), which involves conceptions of deserts in general and other desert-topics such as climate, soil, animals, plants and people living in deserts. Thus, the research questions discussed here are: What kinds of conceptions do students have on how deserts form? What kind of conceptions do students have on the location of deserts?

Method

An appropriate methodical approach needs to fit to the aims of the study (Wilson, 1982) and the current state of research (Bortz & Döring, 2009). To explore the so far unkown conceptions in their depths, qualitative methods are most suitable, because of their open and explorative character (Kelle & Erzberger, 2004; Lamnek, 2010; Mayring, 2002; Patton, 2002). Furthermore, the substantial gaps in the current state of research do not allow realizing a hypothesis-testing study. Interviews are a very common qualitative method to collect students' conceptions (e.g. Hopwood, 2004; Kortz & Murray, 2009; Rappaport, 2009; Vosniadou & Brewer, 1992). Among the different interview techniques semi-structured and problem-centered interviews (Lamnek, 2010; Mey & Mruck, 2007; Reinders, 2005; Witzel, 2000) are the most adequate to explore students' conceptions. Following this technique the basic structure of the interviews is given by using an interview guide, whilst ad-hoc-questions are still possible at any time. Thus, the individual conceptions can be explored in their depths (ad-hoc-questions) and compared with each other (interview guide) at the same time. In addition, other comparable research approaches (e.g. Hopwood, 2004; Rappaport, 2009) used similar types of interviews.

The number of interviews was chosen with a view towards the concept of "theoretical saturation" (Glaser & Strauß, 2009). Therefore, interviews were conducted until the point of redundancy was reached. This means, the sampling can be terminated when no new information is forthcoming from newly sampled units (Lincoln & Guba, 1985). Following this approach it is highly important to maximize the sample's

variation (Patton, 2002) to ensure the assessment of diverse conceptions. Therefore the selection of students was executed within an already fixed sample structure, yet the selection was random (Flick, 2007). This meant only two students per class and only six students per school were chosen randomly. In addition, the three selected schools were in different German federal states. In the study at hand, the point of redundancy was reached after nine interviews, yet four more interviews were carried out. The final sample can be described as follows: thirteen interviews were conducted, all students were in grade 7 (because instruction on deserts starts at grade 7 and in this study the conceptions before instruction are explored); none of them had instruction on the topic "deserts" before; seven were age 12 and six were age 13; four male and nine female students; five students from a metropolitan, four from an urban and four from a rural school district; and five students with and nine without travel experience to deserts. It is important to note that the criteria mentioned are used as indicators to maximize the sample's variation and can not be seen as predictors or independent variables as in quantitative studies.

The students' preconceptions of several desert topics were surveyed, including the formation and location of deserts.The interview guide contained five obligatory questions (see table 1) concerning the last-mentioned aspect, ad-hoc-questions were allowed during the whole interview to receive a complete picture of the students' conceptions. To ensure the the interview guide's quality it was discussed within the working group and tested and improved in pre-tests (n = 6). Each interview took between 54 and 88 minutes.

Table 1.
Interview guide concerning formation and location of deserts

Questions	Instruction for the interviewer
[...] Where are deserts located? Please mark the areas, where you think that deserts can be found!	give student a world map, ask to "think-aloud"
Why do you think deserts are located in the areas you just marked?	ask questions regarding the world map and detailed ad-hoc-questions
Why aren't there any deserts north/south/west/east of the marked areas?	ask questions regarding the world map and detailed ad-hoc-questions
Have there always been deserts? Why (not)?	ask questions regarding the world map and detailed ad-hoc-questions
How do you imagine the deserts were formed?	ask detailed ad-hoc-questions concerning the causes and the process of desert formation

The interviews were transcribed and edited for reading purposes. Furthermore, the students' statements were analyzed by using qualitative content analysis methods (Gropengießer, 2005; Mayring, 2000). Thereby the computer software MAXQDA was

used (Kuckartz, 2010). Firstly, the students' conceptions were analyzed on an individual level to get deep insights into the ways students imagine the formation and location of deserts. As a second step, further analysis went beyond this individual level, aiming at the identification of supra-individual elementary models of conceptions. Therefore, the individual conceptions were compared with each other (Lamnek, 2010). This internal comparison (Janßen-Bartels & Sander, 2004) focused on basic similarities and divergences (Kelle & Kluge, 2010) of the individual conceptions. As a result of this step, students' preconceptions are available as generalized statements, like in other similar studies (e.g. Hopwood, 2004; Dittmann, 2009).

The quality of the results was established by conducting the above stated steps gradually. Independent analysis and mutual control (i.e., computation of intercoder reliability (Holsti, 1969); R = .85), as well as a discussion of interpretations within the work group, triangulation through multiple analysts (Patton, 1999) and a precise documentation of procedural stages ensure intersubjective replicability (Mayring, 2002; Steinke, 2004).

Findings and discussion

In the following, selected individual conceptions are presented (for complete transcripts and revised versions of all students see Schubert, 2012). These are illustrated with extracts from the transcript and the revised version. Concerning desert formation, the students' statements were additionally transformed into flow charts to show the conceptions at a glance. Furthermore, concerning the location of deserts, world-maps filled out by students are presented. The following discussion of chosen aspects is focused particularly on central elements of their conceptions. Furthermore, possible origins of the conceptions are presented and how deep-structured the conceptions seem to be is discussed. Finally, the generalized conceptions as results of the comparative analysis of all 13 interviews are explained.

Formation of deserts

Individual Conceptions

The formation of deserts is, in Carlotta's conceptions, a natural thing. "People are not accumulating sand" (Carlotta, 124-125). The process of desert formation starts with the ocean; she thinks that the ocean floor consists of sand. As a next step, the sea level has fallen, all the water has gone, but the sand of the ocean floor stays (see Figure 1). "That is why there is a desert and no ocean anymore" (Carlotta, 126-127, 135).

Lisa imagines the formation of deserts takes a very long time. "I believe a desert is formed very slowly" (Lisa, 175-176). The process of desert formation (see Figure 2) begins in her conceptions with a ocean's desiccation. "When an ocean has dried out, then you got at first the sand and a surface which is completely warm and dried out" (Lisa, 87-90).

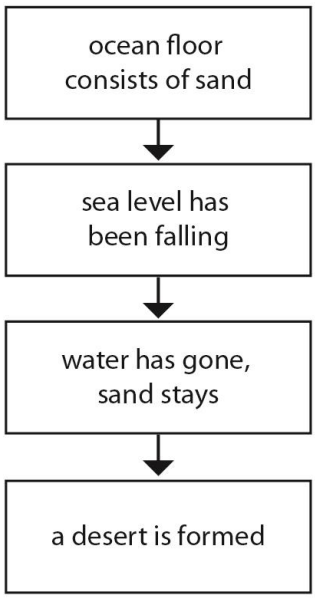

Figure 1.
Carlotta's conceptions concerning the formation of deserts

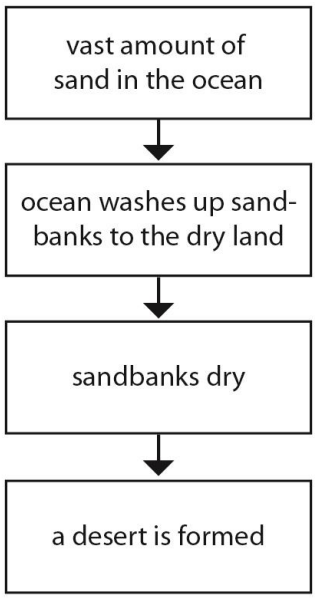

Figure 2.
Nina's conceptions concerning the formation of deserts

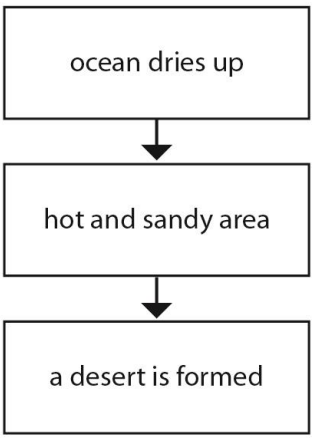

Figure 3.
Lisa's conceptions concerning the formation of deserts

Nina's conceptions also start with the ocean (see Figure 3). "There is a lot of sand in the ocean. In former times, maybe the ocean wasn't as big as today and there were lots of sandbanks. These sandbanks were washed up to the dry land and dried. At these places the Sahara and the other deserts were formed" (Nina, 113-116).

Carlotta, Lisa and Nina have similar conceptions concerning the formation of deserts. Carlotta's and Lisa's conceptions especially show a lot of similarities, while Nina's starts with the same thoughts of sand in the ocean, however it is not the ocean falling dry but the ocean washing the sand to the dry land.

Finn thinks that deserts have existed for a long time. "Deserts exist for quite a long time. In the past, the ancient Egyptians have built their pyramids mostly in the deserts. That's why there must be deserts for quite long" (Finn, 115-118). Finn explains the formation of deserts with strong winds that amassed the sand (see Figure 4): "In former times the earth consisted only of sand, ice, water, and rock. The sand was spread all over the world. Later on, strong winds amassed it. That is how deserts were formed" (Finn, 124). Finn doesn't specify the locations where this happens, but in his conception the sand is a layer located over the original surface. "Where the sand is blown to, the soil has been a tapped tight layer of earth before or something like that. And that is covered with sand. Then this layer gets thicker and thicker" (Finn, 221-224).

Mirco describes the formation of deserts in a very similar way like Finn does. "In former times, there were no deserts, back then the sand was spread all over the world. The wind has blown together a lot of sand, so that deserts were formed in several

places" (Mirco, 84-88). Mirco thinks wind blows constantly in similar directions and there are certain places where winds meet. In these special areas the sand is accumulated and a desert is formed (see Figure 5).

Both Mirco and Finn believe that sand is spread all over the world and that winds carry sand and amass it. They consider the wind as the central factor in the process of desert formation.

Comparing Finn's and Mirco's conceptions with Carlotta's, Lisa's and Nina's, it can be stated that these are two different ways to explain the formation of deserts, one dealing with the ocean, one dealing with the wind. But there is one common aspect – all five students are arguing about the origin of sand when trying to explain desert formation.

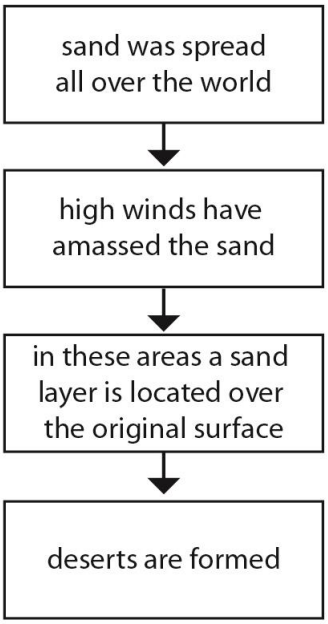

Figure 4.
Finn's conceptions concerning the formation of deserts

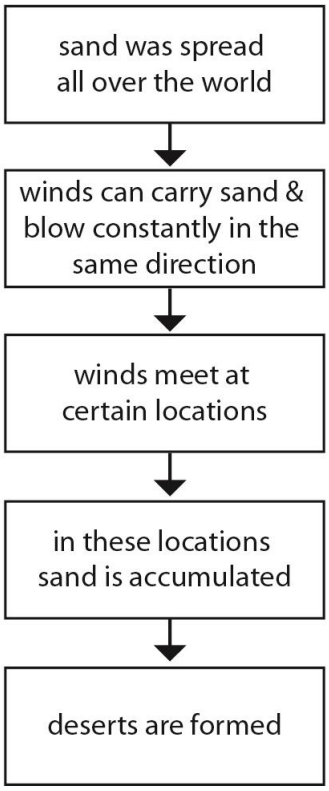

Figure 5.
Mirco's conceptions concerning the formation of deserts

Another interesting conception can be found in Celina's statements. She thinks that there is a vast amount of sand under the ocean. The ocean washes up the sand to the dry land and afterwards the sand dries. Up to this point, Celina's conceptions are similar to the ones concerning the ocean as the origin of the sand. But from this point, Celina uses the wind to explain desert formation, like Mirco and Finn did. Celina thinks it is the wind carrying the sand to a certain place and at that place a desert is formed. That

means Celina combines the above-stated conceptions: The Ocean as the origin of the sand, and the wind as the factor that amasses the sand at certain places. Additionally, again it is sand that is the central factor in the conceptions.

Besides Celina's conceptions that combine ocean and wind, other students could be found using both the ocean and wind conception but without linking them together. The conceptions exist in a parallel unconnected way.

In summary, it can be stated that the students' conceptions are quite complex; some differ more from the scientific perspective than others. In addition, the individual conceptions are, of course, unique, but similarities can be found.

Generalized Conceptions

These basic similarities between in detail differentiated conceptions and fundamental divergences between the conceptions were used to identify generalized conceptions. As a result of these analysis four general conceptions concerning the formation of deserts could be found.

1. Deserts grow out of the oceans' sand (03, 04, 06, 08, 15)[1]

This conception can be divided into two sub-conceptions. Some students imagine that deserts form when oceans dry up (03, 04, 15); other students think that deserts are created from sand washed up by oceans (06, 08). In both cases, these ideas clearly reveal that students see sand as a crucial element of deserts.

2. Wind amasses sand with the result that a desert forms (01, 05, 06, 08, 09, 12, 16)

Wind is the essential factor in this conception. Wind transports and amasses sand so that deserts form. But apart from the basic core that wind creates deserts their conceptions differ and vary. Some students imagine that sand covers an already existing landscape (05, 06, 09). This concept goes along with another concept which implies that a huge layer of sand covers the Earth's surface (05, 06, 08, 09, 10, 13, 15, 16, 17). Sandstorms are also frequently associated with "desert" – both in this study as well as in Adamina's work (2008).

3. When it is hot and dry sand emerges and a desert forms in exactly this place (08, 10, 15)

Following this line of argumentation, students claim that sand is created when it is dry and/or hot. The formation of sand is equated with or directly connected to the formation of a desert.

4. Deserts have always existed (01, 03, 06, 09, 17)

There is no proper explanation for desert formation in this conception. Instead students simply assume that deserts have always existed. This conception could be interpreted as a means to avoid answering the question. But it could also indicate the student's inability to think in long (geological) periods of time.

[1]Interview codes

When comparing the four general conceptions identified it becomes clear that the crucial and connecting element is the origin and/or formation of sand. Most students do not only equate the desert with sand deserts, but also equate the formation of sand with desert formation. Due to the finding that sand is the core element not only in explaining how deserts form, but also in nearly every aspect concerning students' conceptions of deserts, it is evident that this conception is "deep structured" (Niedderer & Schecker, 1992).

The conceptions seem to originate in everyday experiences. To think of the ocean as the origin of sand is probably because of the common experience to discover vast amounts of sand on a beach and on an ocean's ground that can be viewed from the shoreline. If one takes into account that the students do not have an explanation for the formation of sand, it is more than understandable that they rely on daily experiences.

The same is also true for the wind conceptions: they could originate from daily experiences of the transport of sand by wind as witnessed at the beach. Other possible origins could be media reports; for example, press reports on Saharan sand that can reach as far as central Europe and Germany. Other reports on spectacular sand storms could serve as the origin as well. Interestingly, sandstorms are also frequently associated with deserts – both in this study as well as in Adamina's work (2008).

Location of deserts

In the first step, the conceptions of two students are described in an exemplary manner in more detail before the generalized conceptions are clarified.

Individual Conceptions

With regard to the location of deserts, Marie thinks of deserts not being in cooler areas. What is more, in areas without sand, there cannot be deserts either. In her conception, deserts are rather in the warmer south. "The farther you go into the south, the warmer it gets, so there are deserts more likely" (Marie, 109-110). On a world map, she draws as deserts the southern tip of Africa and the south of South America (see Figure 6). As additional criteria for the location of deserts, Marie names aridity and the inland. "Deserts are not directly by the sea, because deserts are dry. That's why you can't grow anything there, because the soil is so bad and they get so little water there. But if a deserts was directly by the sea, they would have enough water" (Marie, 97-98). In addition, she explains the location of deserts being inland because of the temperature. "By the sea, the wind always comes from the sea and then it is no longer that warm. That's why I would say that the desert is rather in the middle" (Marie, 99-102).

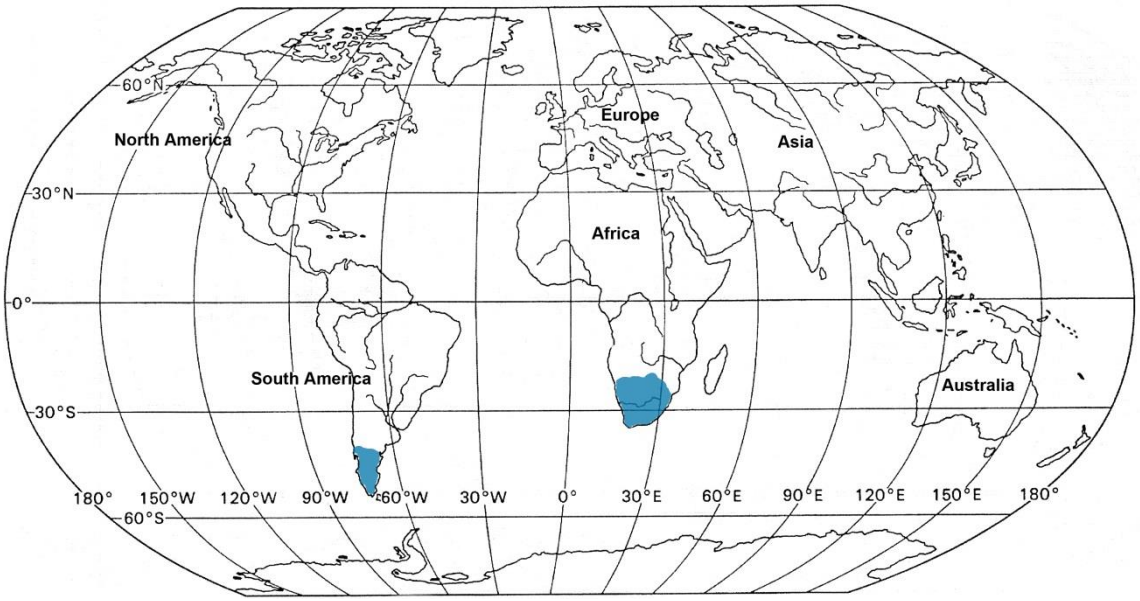

Figure 6.

World map with desert areas marked by Marie

For Celina, deserts predominantly are located in Africa; it's only there where she draws desert areas on the world map (see Figure 7). "In Africa, everything is full of deserts" (Celina, 91-96). For this conception, she gives different reasons. Firstly, she names the equator: "At the equator it is hottest and not that cold because it is in the middle and maybe just there the sun shines close. So deserts can best be formed next to the equator" (103-106). Celina, however, does not imagine deserts being all over the world near the equator, for in densely populated or heavily travelled areas deserts cannot form. "In Central America, maybe there are no deserts, even though it lies near the equator, because it is built-up densely. In South America or America, in Ecuador or in these countries around there, there are also a lot of things going on" (Celina, 100-102). Africa, however, is described as poor, barely built-up, scarcely populated and less travelled to, and that is why she imagines deserts to be there. Celina argues mainly from human beings, for example she says that the people in Africa could force back the desert if they were richer: "In Australia and South America, there are no deserts, because Africa is also a poorer country. And in Australia and South America, there live people who build-up the land much. If Africa was such a country, too, I surely believe that the deserts would be over-built there, too, by hotels and such" (Celina, 107-108).

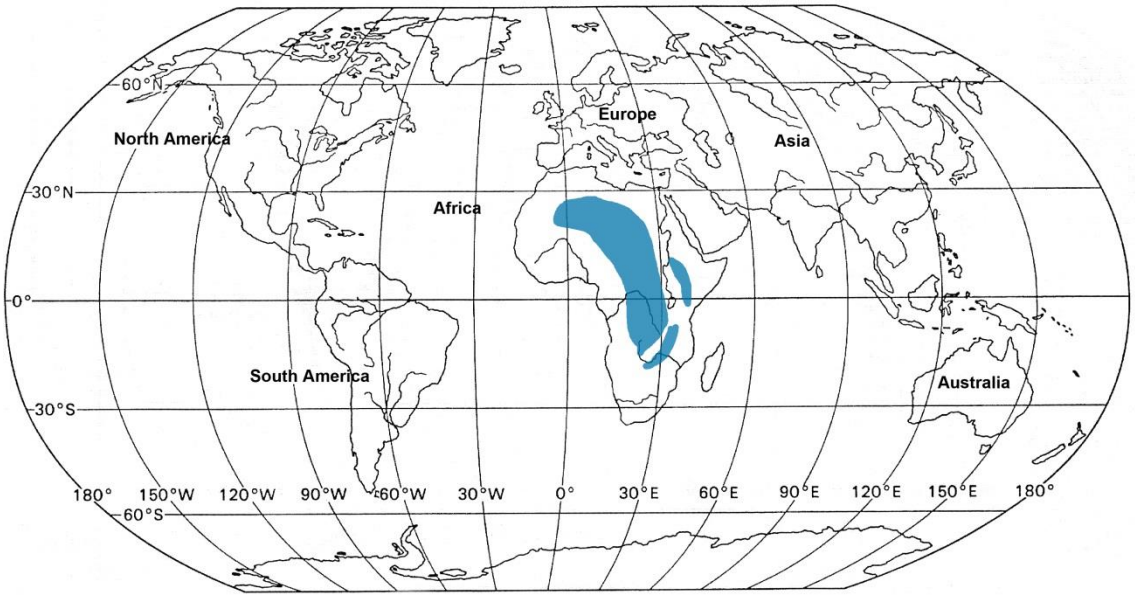

Figure 7.
World map with desert areas marked by Celina.

Generalized Conceptions

Comparing the students' individual conceptions of the location of deserts, certain commonalities and yet also differences can be found. Upon this comparison, the following basic generalized categories can be formulated:

Deserts particularly lie in Africa, however, not in Europe (01, 03, 04, 05, 06, 08, 09, 10, 12, 13, 15, 16, 17)

The areas marked as deserts on the map cannot be analyzed in greater depth on the level of certain countries due to the uncertainty in measuring methods resulting both from the students' use of the map and their handling of the location of several countries. However, from the pupils' statements and drawings two basic commonalities can be stated, which are not to be taken into doubt even by the aforementioned methodical uncertainty. First of all, the conception that there are deserts in Africa is firmly established by all interviewees. In contrast, none of the interviewed students has the conception of deserts being in Europe.

Deserts are located near the equator (03, 05, 08, 09, 10, 13, 15, 17)

The location of deserts is explained in this conception by the equator. The reason given for this is the heat at the equator. The heat itself is explained by the sun, only that the students give different reasons for the high temperatures resulting from the sun in the equatorial area: the sun stands near the equator, the sun stands high above it, the sun shines down perpendicularly, or the sun shines stronger.

Deserts are located in the south or in the southern hemisphere (04, 06, 08, 12, 13)

Within this conception of their location, deserts lie in the south or in the southern hemisphere. Locating them in these areas is linked with the conception of high temperatures; for particular students it gets ever-warmer going south and to the north, deserts are limited by low temperatures. Overall, it becomes clear that the south is equated with high temperatures and the students' explanations are again built on heat.

Deserts lie in the inland or not directly by the sea (03, 04, 05, 06, 08, 09, 10, 12, 13, 16)

In this conception, deserts lie rather in the interior of a continent and not directly by the coast or the sea. This is because at the coast or next to sea there is much water or more rain falling. Some students also mention the wind, which blows away the sand directly next to the sea or the sea itself that washes away the sand – central in each of these cases, however, is the factor "water."

Deserts are not located close to rivers (03, 04, 06, 09, 12)

Deserts not being located close to rivers or in areas with many rivers are at the core of this conception. An explanation is provided based upon the water that is in these rivers. Within the students' conceptions, there is no or hardly any water in deserts, thus deserts cannot be in the areas of rivers.

Deserts are not located in tilled areas (01, 04, 05, 06, 08, 17)

Development and thus human influence play a key role for the location of deserts in this conception. Deserts can only form where there is no or hardly any development. Following this, some students exclude the possibility of deserts being in European areas since humankind has built-up everything there, leaving no space for deserts.

Deserts are not located where there is no sand (04, 12, 13)

Within this conception, the presence of sand is the decisive factor for the location of deserts. Students argue that in areas where there is no sand, deserts cannot be either. The strong connection between desert and sand is evident in this conception.

Criteria for the description and explanation of locating deserts can be condensed into four central aspects. Heat, drought and the conceptions of deserts being only in undeveloped areas or not being in areas without sand can be identified as key criteria.

Both conceptions – that deserts lie near to the equator or in the very south – refer to heat as a central criterion for deserts. At a closer look, heat is the superordinate criterion within this conception, whereas proximity to the equator and southerly position are the manifestations or differentiations. Heat can also be identified as a central element within the imaginative world of the students in other thematic areas.

The observations made here regarding the heat also apply to the conceptions that deserts do not lie next to rivers or the sea: superordinate criterion is the lack of water; rivers and the sea are differentiations of this criterion. Lack of water or aridity is also a central element in the students' conceptions, being mentioned for different topics, too.

The conception that deserts cannot be where there is no sand also works with a key criterion for deserts: sand. Based upon these findings, it can be stated that central

conceptions about deserts – heat, aridity and sand – are used as the basis for describing and explaining the location of deserts.

Beyond these as a further important conception about the location of deserts, anthropogenic influences have to be considered since some students imagine deserts being only in untilled areas. This corresponds with the desert criterion "void," which students attribute to deserts. Regarding the exact localization of deserts, great uncertainties must be stated and an application of spatial grids for orientations can hardly be seen. Similar findings are shown by Blömer (2012) regarding the conceptions of students at the end of grade 6 of the spatial spread of tropic rainforests. In addition, Adamina (2008) has shown that children do have conceptions about certain landscapes; however, not a concept of their spatial spread.

Only a few students connect conceptions of the formation of deserts with their location; conceptions regarding this are of little consistency. Obviously, formation and location of deserts are considered to be separate categories, with connections being drawn only implicitly. At the same time, the students' criteria for deserts (heat, aridity, sand, and void) are used consistently. This suggests that these conceptions are deep structured.

Conclusions

This study provides deep insights into individual students' conceptions concerning formation and location of deserts. In addition, basic similarities and differences between the individual conceptions were found. Those led to the formulation of generalized conceptions. These findings provide substantial enhancements to the current state of research because the so far unkown conceptions concerning the location and formation of deserts could be identified. Furthermore they give insights into students' deeper thinking regarding these topics by considering not only terms associated with deserts but also explanatory processes constructed by the students. With regard to the research on didactics of geography, the present results form an important basis for further empirical studies. As a next step, for example, a questionnaire can be created based upon the qualitative findings of this approach, aiming for a quantification of the conceptions related to this topic. Such a questionnaire can also be used in distinct countries to make a comparison between the conceptions of students with different backgrounds.

Concerning consequences for geography lessons it has to be stated, that this qualitative study shows what kind of conceptions the interviewees have. At the same time it doesn't make any statement about the conceptions' quantity and factors of influence. That is why the following consequences should be seen only as theses, which are based on the study's findings, but not yet empirically evaluated.

In general, the focus should be on deconstructing the sand stereotype conception as this conception is dominant in causing the students' thoughts on different topics to be single-sided and limited to sand and sandy deserts. Guiding students to reflect on the origin of their conceptions (Krüger, 2007; Möller, 2010) could be a promising way to deconstruct this conception. In addition, the students' conception of a desert as a sandy

desert needs to be contrasted with scientific concepts. Furthermore, the formation of sand should be treated as an individual topic, as the sand is of central significance for the students; however, they do not have adequate explanations for its origin. It can be expected that some of their everyday life conceptions of the formation and location of deserts may be less important if the students had established an adequate desert image before.

To build up an understanding of the formation and location of deserts that goes beyond mere description, the climatic conditions leading to the location and emergence of deserts should be dealt with in classes. Thus, tropic circulation should either be taken up in advance or integrated into the topic of "deserts." In doing so, the temperature and even more the precipitation conditions are clarified so that, above all, the decisive basis for an understanding of location and origin of deserts is established.

The same thing also applies to other desert types, such as rain shadow deserts or coastal deserts: Without the knowledge of basic climate interrelationships, the location and formation of desert areas can only be dealt with in classes on a descriptive level, thus a profound understanding cannot be achieved.

In addition, regarding the dispersal of desert areas over the Earth's land surface, spatial distribution patterns and related explanations should be made an educational topic. Moreover, it appears worthwhile to take this topic as an example to clarify the steps of comprehending and explaining spatial structures as a key aspect of geographical thinking and working.

Concerning teacher education and professional development activities, teachers need to develop knowledge about students' conceptions concerning deserts and the formation of deserts so they can adequately address them in teaching. Also, textbook editors and curriculum material developers could use this knowledge for designing books and materials more carefully, especially when displaying photos of sandy deserts as the only means to represent deserts.

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