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Subject-Specific Correctness of Students' Conceptions and Factors of Influence: Empirical Findings from a Quantitative Study with Grade 7 Students in Germany Regarding the Formation and Location of Deserts

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Abstract

Students' conceptions are a central learning condition. Until now there have only been qualitative results regarding the important geographical area of the desert, especially its location and formation. Therefore this study surveys students' conceptions (N = 585; n = 448 without pre-instruction on deserts and n = 137 with pre-instruction on deserts) with the help of a questionnaire containing open and closed questions. The descriptive as well as inferential statistical analysis shows that both subject-specific correct as well as subject-specific unfounded explanations regarding the location and formation of deserts are frequently found. At the same time, the conception about deserts being just sandy deserts is strongly connected with the subject-specific correctness of the conceptions regarding the location and formation of deserts. Based on the discussion of the results, information about the possibility of future research is given.

Keywords

Students' Preconceptions, Desert Formation, Desert Location, Quantitative Study, Secondary Geography Education

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The learning requirements of students play an important role within learning processes. In this study, conceptions are understood as "subjective cognitive constructs" (Gropengießer, 2007) in terms of a moderate constructivist understanding (Gerstenmaier & Mandl, 1995; Reinfried, 2007; Reinmann & Mandl, 2006; Riemeier, 2007). They can be classified regarding their complexity, ranging from basic (terms) to complex (subjective theories) (Gropengießer, 2007; Gropengießer, 2010). At the same time the degree of anchorage of conceptions may vary, whereby stable (deep structure) and transient (current construction) conceptions are distinguished (Niedderer & Schecker, 1992). Already existing conceptions regarding one topic, one region, one method or a given subject play an important role next to other requirements such as intelligence, interest and attitude (Helmke & Schrader, 2010), since they present starting points for learning, while, at the same time, they could be potential obstacles to learning (Duit, 2006; 2010). Both for the construction of teaching material as well as in concrete classroom situations, knowledge about expected typical alternative conceptions are helpful and necessary to make appropriate didactic decisions and to enable these conceptions to be addressed. In this context, empirical studies using qualitative methods can provide insights into the depth as well as complexity of the conceptual worlds of individual students, as well as the provision of generalized conceptional categories that apply to more than just one student. At the same time, qualitative interview studies tend not to produce authoritative results about the frequency of occurrence of certain conceptions, since relatively few students are analyzed. Yet knowledge about frequencies would seem to be very helpful for the construction of teaching material. Teachers' awareness of typical, likely-to-occur student conceptions could also be beneficial in concrete classroom situations. Knowledge about possible influencing factors on these conceptions is also of interest in this context.

The desert as a classroom topic is of great significance in geography education of grade seven in German schools. In this regard studies about students' conceptions (without previous teaching) on this topic are available (Adamina, 2008; Dove, 1999; Schubert, 2012; 2014; 2015), however the authors only collected data in the form of associations of deserts in general (Adamina, 2008; Dove, 1999). More differentiated results can be found in the qualitative interview studies of Schubert (2012, 2014, 2015), which point out pre-instructional conceptions ("preconceptions") of individual subject areas. Yet any results regarding which of the collected preconceptions occur frequently and which occur only occasionally are missing. Furthermore the relevance of possible influencing factors such as interest, gender etc. is unknown. This is also true for students' with previous instruction on deserts.

To fill this gap in research, quantification has to be conducted as well as an investigation of potential influencing factors. The basis for this research are the results from the qualitative study on pre-instructional conceptions of students about the location and formation of deserts (Schubert, 2014) with the following central findings:

Students indeed already offer numerous pre-instructional criteria for the location of deserts, but they are not aware of a zonal pattern. These results are consistent with the findings of Adamina (2008, p. 177). Furthermore a number of conceptional categories regarding the location of deserts can be identified: Deserts are located on the equator or in the south/on the southern hemisphere because it is particularly hot there, deserts are

located inland and not close to the sea, deserts are not located close to rivers and lakes, deserts are located in areas that hold a lot of sand, and deserts are located in empty, unbuilt areas (see Schubert, 2014 for full details).

Complementing the previous findings, four conceptional categories regarding the formation of deserts were identified: Deserts emerge from the sand of the sea, wind blows deserts together, deserts always existed, and heat and drought form sand until a desert develops. At the same time an interest study (Mohn, 2015) revealed that students show a rather high interest in the formation of deserts compared to other sub-areas of deserts (*mean* = 3.98 on a 5-step Likert scale, *N* = 345) and also their interest in the location of desert areas is located well within the positive area, with a mean value of 3.37.

Against this background the following research questions are primarily discussed within this project:

- Which conceptions do students of the seventh grade possess regarding the topic areas location and formation of deserts, and how frequently do they occur?
- Which role does instruction on deserts play for the subject-specific correctness of students' conceptions?
- Which relevant predictors for the conceptions regarding location and formation of deserts can be identified?

Methodology

Questionnaire Design

The questionnaire is composed of three parts (see Table 1). In the first part, A, open questions were purposely used to gather individual previous knowledge and associations of the students regarding the topics of desert, and the location and formation of deserts.

Table 1
Structure of the Questionnaire

Part A	Open tasks Associations with the desert, ideas of formation and location
Part B	Assessment of 43 items on a five-step Likert-type scale Ideas of formation and location of deserts
Part C	Independent variables: age, gender, performance level / grade in geography, interest in the subject geography, interest in the topic deserts, pre-instruction on deserts, extracurricular engagement with deserts, and travel experience in desert areas

In Part B of the questionnaire, students were asked to rate 22 items regarding the location, and 21 items regarding the formation of deserts according to agreement with the given statements with their personal ideas. In order to achieve this, a five-step Likert-type scale was used (1 = not at all, 2 = hardly, 3 = in part, 4 = mostly, 5 = completely). Thereby the methodical approach for the formulation of the questions in the questionnaire was

similar to a study on the conceptions of cell division (Johannsen & Krüger, 2005, p. 28), the construction of the rating scale was geared to a study on the conceptions of evolution (Jonas, Riemeier, & Krüger, 2004). The formulation of the items was carried out under dependence on concrete statements made by students, taken from the studies of Schubert (2012, 2014) and transferred into suitable statements for items. After the statements were developed, a randomization was conducted in order to achieve a random arrangement of the items (Moosbrugger & Kelava, 2012).

Part C of the questionnaire was used for the registration of personal data. Thereby the gender and age of the test persons, as well as their interest in geography and in the topic desert were recorded. Beyond that, the familiarity of the test person with the topic was detected, for example from geography lessons, own experience from vacations or travel documentaries and newspaper articles. Finally their proficiency level in the subject geography was recorded with the help of a five-step scale (very good to deficient).

Pretesting, Statistical Characteristics, and Missing Data

The questionnaire was tested as to its comprehensibility or appropriateness regarding test theory. For this, an expert rating (24 university students in the master's program in Geography Education, University of Münster) was used among others. In advance four pupils finished the questionnaire of the survey, while the methods "Concurrent-Think-aloud", as well as "Paraphrasing" (Prüfer & Rexroth, 2000) were used. Furthermore, an investigation of Part B of the questionnaire was carried out by means of statistical analysis. In doing so, difficulty of items of the questionnaire used for the main study appeared (with only two exceptions) to be within an acceptable medium range between .2 and .8 (Bortz & Döring, 2006, p. 219). The average item difficulty of the scale for the location of deserts was .62 and of the scale for desert formation .67. The calculation of selectivity (the correlative connection between single item values and test values) showed unsatisfying results for both sub-scales, with only 16 out of 43 items located over the critical value of .30 (Bortz & Döring, 2006). This means that many items measured something different than the sum of all remaining items, namely the test value. With regards to content, this result was expected and logical, since the items represent conception models with different content that students may possess parallel to each other. Therefore these items remain in the test despite their low selectivity. The reliability of the full scale may therefore also be under the critical value of .80 with Cronbach's $\alpha = .667$ due to the above-mentioned reasons (Bühner, 2006), but can still be counted as acceptable in the face of the explorative character of the study (Lienert & Raatz, 1998).

The original data was used for the whole analysis of Part A of the questionnaire as well as for the descriptive analysis of Part B, especially on the level of the single items. Both for the analysis of the factors (see below) as well as for the calculation of the influence of the independent variables (see below), the method of multiple imputation (Böwing-Schmalenbrock & Jurczok, 2012; Newman, 2014; Peugh & Enders, 2004) was used regarding missing data in the closed Part B of the questionnaire. Therefore $m = 5$ imputation data sets were produced. All details on the factor analysis as well as on the influence of the independent variables are based on those $m = 5$ imputation data sets and data such as the mean value, F-values etc. are averaged on the imputation data sets

following the rules of Rubin (1987; cf. also Schafer & Olsen, 1998; Van Ginkel & Kroonenberg, 2014).

Dimensionality Reduction

In the framework of an explorative factor analysis of the items in Part B, six empirical sub-scales unfold which meet the reliability criteria of explorative studies with Cronbach's $\alpha > .50$ (Lienert & Raatz, 1998) (see Table 2). Two subscales refer to the formation of deserts and differentiate in so far as they explain the formation either through sea or wind. Three subscales summarize items regarding the location of deserts. Thereby the location in unbuilt areas without sand, location on the southern hemisphere, as well as location on the equator are differentiated. The sixth subscale combines aspects that refer to the location as well as the formation of deserts and explains them through drought in the form of content.

Table 2
Empirically Formed Subscales Regarding the Formation and the Location of Deserts (Note: Mean = 5 Would Be Subject-Specifically Correct Conception)

Subscales	***α***	***Mean***	***SD***
Formation through sea	.747	3.23	0.84
Formation through wind	.712	3.18	0.83
Location in unbuilt areas without sand	.597	3.24	0.86
Location in the southern hemisphere	.661	3.22	0.98
Location at the equator	.595	2.57	0.95
Location and formation explained through drought	.614	3.59	0.84

Sampling, Implementation and Analysis

Grammar school (in German 'Gymnasium') students of grade seven were chosen for the survey because the topic desert is taught in grade seven according to the core syllabus (cf. Ministerium für Schule und Weiterbildung des Landes Nordrhein-Westfalen, 2008). Since the survey was conducted around the end of the first half of the school term, some students had already had instruction on deserts, while others had not. Due to this, evidence on the effectiveness of teaching in relation to the subject-specific correctness of the preconceptions was expected. A total of 585 students of the grade seven in 25 different classes from 10 different grammar schools in North Rhine-Westphalia were surveyed. The analysis was performed with the help of the statistical analysis program SPSS (version 23).

Findings

Description of the Sample

The sample included a total of 585 students, thereof 276 males and 285 females (not stated: 24). The average age of the test persons was 12.49 years (SD = 0.64, min = 11,

max = 16, not stated: 33). Of the 585 students, 448 (76.6%) had not yet had instruction on deserts in their geography classes, 137 students (23.4%) had. The average interest in geography was rated with 3.45 (five-step scale, $n = 568$, $SD = 1.0$). Therefore interest in the subject geography is clearly above the medium of the scale of 3.0. Student interest in the subject "desert" is also within a positive range (*mean* = 3.11, $n = 569$, $SD = 1.1$). Furthermore 80 students stated they had already been to a desert (for example on holiday). Four hundred thirty-nine students had already seen movies or documentaries on deserts outside the classroom.

Results of the Open Part A of the Questionnaire

Conceptions on the appearance of deserts. A central result of the qualitative study (Schubert, 2012; 2014) was that students first and foremost view deserts as sandy deserts. This conception seems to be deep-seated. Furthermore, students also use this conception in other subject areas of deserts, for example when explaining their formation. For this reason the open part of the questionnaire surveyed how students imagine the appearance of deserts. The results were allocated to three categories: A description of the appearance a) exclusively as sandy deserts, b) as sandy deserts, but mentioning other types of deserts like rocky or stone deserts, and c) in the form of different types of desert in the sense of a differentiated image of the desert. The process showed (see Table 3) that most students see deserts exclusively as sandy deserts (64.5%). About one quarter (26.6%) describes an image of the desert as a sandy desert, but at least name other types. Only 8.9% showed a differentiated image of the desert. A significant difference was found between students with and without instruction on the topic desert, $\chi^2 (2) = 133.08$, $p < .001$, $V = .486$, which classifies the effect of instruction as strong. Students with instruction on the topic show a clear conception of the desert significantly less often, but they more frequently know other types of deserts or they even possess a differentiated image of the desert.

Table 3
Frequency of Preconceptions on the Appearance of Deserts; Not stated or incomprehensible: n = 21

Image of the desert	All students (n = 564)		Without teaching on deserts (n = 435)		With teaching on deserts (n = 129)	
	n	%	*n*	%	*n*	%
a) exclusively as sandy deserts	364	64.5	330	75.9	34	26.4
b) sandy desert dominates, but other types of deserts are mentioned	150	26.6	92	21.1	58	45.0
c) differentiated image of the desert	50	8.9	13	3.0	37	28.7

Conceptions on the location of deserts. As part of the section with open questions (Part A) students were first asked to mark those regions on an empty world map where they imagined deserts to be located. The drawings were encoded by different assessors, but they still have only a limited informative value since order patterns can only be deducted indirectly and interpretatively. The criteria or order pattern *deserts are located inland* was encoded most frequently at 260 times. Almost half of the students showed this imagined location (see Table 4). Two hundred twenty students (38.1%) marked deserts at the *subtropic/outer tropic belt of high pressure*. Both order patterns are correct from a subject-specific perspective. However subject-specifically incorrect patterns were also frequently found: 214 students (37%) marked regions at the equator as deserts, almost one quarter of the students (133 or 23.1%) marked the southern tip of continents, namely the south of South America and Africa. Comparing students with and without instruction on deserts, statistically significant differences were found with the help of χ^2 tests. The biggest difference regarding subject-specifically correct descriptions of the location were found *in the region of the subtropic/outer tropic belt of high pressure*, which was encoded much more frequently with students who had already had instruction. The effect size was classified as moderate with $\varphi = .224$. This implies the building of subject-specifically correct order patterns through instruction.

Table 4

Markings of the Location of Deserts on a World Map Encoded in Order Patterns, Multiple Encoding Possible (N = 577); not stated: n = 8

Deserts are located …	All students (n = 577)		Without teaching on deserts (n = 448)		With teaching on deserts (n = 137)		χ^2 df = 1	p	φ
	n	%	n	%	n	%			
inland	260	45.1	180	40.2	80	58.4	12.90	< .001	.150
at the subtropic/outer tropic belt of high pressure	220	38.1	141	31.5	79	57.7	29.07	< .001	.224
at the equator or the region of the equator	214	37.1	171	38.2	43	31.4	2.50	ns	
in the southern tips of the continents	133	23.1	89	19.9	44	32.1	8.33	.005	.120

In addition, markings on the world map were analyzed under another perspective by encoding the marked continents. Almost all students (532 or 92.4%) located at least one desert area in Africa (see Table 5). Australia and South America follow with 332 or 322 markings, respectively, on the next two ranks. Two hundred fifty-nine marked deserts in Asia and 186 in North America. Only 21 students (3.7%) marked at least one region in Europe as desert. Comparing students with and without instruction on the topic desert, there is almost no difference in marking deserts in Africa. In Australia, South America, Asia and North America students with instruction marked deserts significantly more frequently; the effect size was classified as low with values ranging from φ = .107 to φ = .147. The reason for this could be the way the location of deserts was dealt with in the classroom.

Table *5*

Markings of the Location of Deserts on a World Map Encoded in Continents, Multiple Encoding Possible (n = 577); not stated: n = 8

Deserts are located on the continent…	All students *(n = 577)*		Without teaching on deserts *(n = 448)*		With teaching on deserts *(n = 137)*		χ^2 *df* = 1	*p*	*φ*
	n	%	*n*	%	*n*	%			
Africa	532	92.,4	410	91.5	122	89.1	2.79	ns	
Australia	332	57.6	240	53.6	92	67.2	6.53	.013	.107
South America	322	56.0	228	50.9	94	68.6	12.44	< .001	.147
Asia	259	44.9	183	40.8	76	55.5	8.14	.006	.119
North America	186	32.2	125	27.9	61	44.5	12.42	.001	.147
Europe	21	3.7	18	4.0	3	2.2	1.31	ns	

Conceptions on the reasons for the location of deserts. In the next step the students were asked to reason the location of deserts. The openly formulated answers of the students were encoded in categories and the frequencies were enumerated whereby multiple answers were possible.

With 397 mentions *heat* was given most frequently as a reason for the location of deserts (see Table 6). With 134 mentions *drought* is ranked second as a subject-specifically correct explanation. The *equator* was mentioned 81 times (rank 3), which makes it, for most students, a criterion for the location and at the same time a reason for the location. With these answers, it is striking that the equator is often equated with heat and is therefore used as an explanation for the location of deserts. Seventy-nine mentions were allotted to *missing or very low amount of precipitation*, as a reason for the location. If these are combined with the mentions of drought minus the number of students who name both drought as well as low precipitation, 184 students mentioned the subject-specifically correct reason *drought or missing precipitation*. Students gave *occurrence of sand* as a reason for a desert's location 31 times, 13 times with the help of *empty or missing settlement*. Subject-specifically correct explanations that went deeper into the chain of explanation and focused on the cause of drought were only mentioned by 12 (*at the subtropic/outer tropic belt of high pressure)*, 10 (*in rain shadows behind mountains*), 5 (*in the inland with far distance to the sea*) or 5 students (*at coasts due to cold sea currents*).

Comparing the group of students with instruction on the topic desert and the group without instruction, shows that the incorrect explanation *heat* was mentioned significantly less frequently by the first group. Instead, the subject-specifically correct explanation *missing rain* as well as *location at the subtropic/outer tropic belt of high pressure* and

location in rain shadows were mentioned much more frequently. The effect size was classified as low to moderate. All in all, this shift implies the building of subject-specifically correct explanations through instruction, even if the percentage frequency of mentions is still on a very low level, even with students that had already been instructed.

Table *6*

Results of the Encoding of the Statements on Reasons for Locations of Deserts, Ordered by Descending Frequency, Multiple Encoding Possible (N = 585)

Desert location explained by …	All students (N = 585)		Without teaching on deserts (n = 448)		With teaching on deserts (n = 137)		χ^2 df = 1	p	φ
	N	%	n	%	n	%			
heat	397	67.9	322	73.0	75	54.7	16.22	< .001	.168
drought	134	22.9	99	22.4	35	25.5	0.31	ns	
(proximity to) the equator	81	13.8	66	14.7	15	10.9	1.26	ns	
missing rain	79	13.5	41	9.3	38	27.7	30.12	< .001	.228
occurrence of a lot of sand	31	5.3	22	5.0	9	6.6	0.376	ns	
empty or missing settlement	13	2.2	12	2.7	1	0.7	1.89	ns	
(location at) subtropic/outer tropic belt of high pressure	12	2.1	2	0.4	10	7.3	24.52	< .001	.205
rain shadow or location behind mountains	10	1.7	2	0.5	8	5.8	17.83	< .001	.176
great distance to the sea and rivers	5	0.9	3	0.7	2	1.5	0.74	ns	
cold currents (coastal deserts)	5	0.9	3	0.7	2	1.5	0.74	ns	
other and incomprehensible statements	91	15.6	74	16.8	17	12.4			
not stated	7	1.2	7	1.6	0	0.0			

At the same time, it is quite striking that the subject-specifically incorrect explanation *equator* was not mentioned significantly less often by students with instruction. The equator as a subject-specifically incorrect explanation plays a quite remarkable role in the

conception of students in both groups and is often connected to the cause heat, which is only of limited accuracy from a subject-specific perspective.

Conceptions on the formation of deserts. The conceptions on the formation of deserts were also collected through open questions (Part A); the statements were encoded in categories, whereby multiple encodings were possible. The results (see Table 7) show that the subject-specifically correct explanation *drought* was mentioned 235 times by the students and therefore was the most frequent response, followed by *wind* (182 mentions), heat (179 mentions), *falling sea level* (88 mentions), *formation of sand from rocks* (36 mentions) as well as *sand washed up by the sea* (26 mentions). Other categories were encoded less than 20 times and therefore seem to reflect single conceptions. This also applies to the rather frequently encoded category *other*, which summarizes a number of individual as well as incomprehensible statements. One hundred seven out 107 of the 585 students did not write a statement, which might be explained by either a lack of motivation when filling in the questionnaire or by them being unable to formulate an independent explanation for the formation of deserts without the help of others.

It is worth pointing out that the subject-specifically correct explanation *drought* was given most often. At the same time subject-specifically incorrect conceptions (especially *formation through wind* and *formation through the sea*) were also found quite often. Wind was mentioned by every third student. If the explanations between the groups of students with and without instruction on the topic desert are compared, results show that many reasons exist in similar percentage in both groups. Alongside two significant differences are found between both groups. On a much higher percentage basis, students with instruction on deserts mention *wind* as well as *rock that turn into sand* as a cause for the formation of deserts more than students without such instruction. The effect size was classified as low to moderate. While *rock that turn into sand* apparently reflects subject-specific teaching content, the frequent mentioning of *wind* as a cause of desert formation is quite astonishing. Wind being mentioned in the classroom, usually in the context of the differentiation of desert types (stone, gravel and sandy desert), is possibly misinterpreted as a cause for desert formation.

Table 7
Results of the Encoding Of the Statements on the Formation of Deserts, Ordered By Descending Frequency, Multiple Encoding Possible (N = 585)

Deserts form through …	All students (N = 585)		Without teaching on deserts (n = 448)		With teaching on deserts (n = 137)		χ^2 df = 1	p	φ
	N	%	n	%	n	%			
Drought	235	40.2	180	40.2	55	40.1	1.44	ns	
Wind	182	31.1	108	24.1	74	54.0	30.49	< .001	.231
Heat	179	30.6	140	31.3	39	28.5	0.63	ns	
Falling sea level	88	15.0	69	15.4	19	13.9	1.97	ns	
Rock turning into sand	36	6.2	6	1.3	30	21.9	36.97	< .001	.251
Sand washed up by the sea	26	4.4	22	4.9	4	2.9	1.25	ns	
Cold currents resulting in drought	18	4.1	14	3.1	4	2.9	0.10	ns	
Deserts have always been existing	13	2.2	8	1.8	5	3.6	0.01	ns	
Desertification/ecological destruction through humans	13	2.2	3	0.7	10	7.3	3.76	ns	
Formation is impossible to explain	6	1.0	5	1.1	1	0.7	0.16	ns	
Other processes	147	25.1	110	24.6	37	27.0			
Not stated	107	18.3	102	22.8	5	3.6			

Results of the Closed Item-Based Part B of the Questionnaire

The results of the item-based Part B of the questionnaire will be presented in reference to the subject-specific correctness of the preconceptions in the following section. Three approaches were used to determine subject-specific correctness:

1. All 43 items are looked at together. Those items with a subject-specifically correct answer on 1 (not at all) are recoded. Therefore category 5 is the uniform highest level of subject-specific correctness for all items. Additionally, the 21 items in substance based on formation, and the 22 items on location, are differentiated.
2. The empirically built subscales, which are also coded in a way that "5" describes the highest subject-specific correctness, are focused on individually.
3. The 14 items that include subject-specifically correct statements on the location (10 items) or on the formation (4 items) of deserts (separated into location and formation) are summarized, and mean values are calculated as a degree of conformity of the student's preconceptions with the subject-specifically correct conception. The same applies for the 29 subject-specifically incorrect items.

If subject-specific correctness is examined on the basis of all 43 items (approach 1), the *mean* = 3.22 (n = 584, SD = 0.32) implies that the test persons possess subject-specifically correct preconceptions, even though the distance to the medium of the scale at 3.0 is rather short. If the mean values are examined separately according to location and formation of deserts, the mean value in reference to location with *mean* = 3.11 (n = 584, SD = 0.37) shows only a very slight trend towards subject-specifically correct preconceptions. Regarding the formation of deserts a mean value of 3.35 (n = 584, SD = 0.43) implies that subject-specifically correct preconceptions prevail in the questioned students.

On the level of the empirically built subscales (approach 2) students possess with the exception of the subscale *location on the equator* more correct perceptions, mean values were between 3.18 and 5.59. Regarding the perception of the location on the equator, the subject-specific correctness of the perception has a mean value of 2.57, which is below the medium scale. Students therefore possess rather subject-specifically incorrect perception in this topic area. This was confirmed by the results of the questionnaire Part A, which indicated that the subject-specifically incorrect perception of location of deserts at the equator plays an important role in the perceptions of the test persons.

As to the 14 subject-specifically correct items (approach 3), the results show the following picture: The subject-specifically correct statements on the formation of deserts reached a mean value of 3.43 (N = 585, SD = 0.72), the statements on the location a mean value of 3.02 (N = 585, SD = 0.48), which was only slightly above the medium of the scale. In contrast, the mean values of the subject-specifically incorrect statements on desert formation (17 items) had a *mean* = 2.68 (N = 584, SD = 0.54), clearly below the medium of the scale (3.0). The mean values of the subject-specifically incorrect statements on the location (12 items) showed the same results with slight differences (N = 584, *mean* = 2.85, SD = 0.64). It clearly shows that students, on average, possess more subject-specifically correct perceptions on the formation of deserts; with regard to the location this trend appears only with limitations. Other studies also point out that

subject-specifically correct perceptions of the spatial distribution of deserts rarely exist (Adamina, 2008; Schubert, 2012, 2014).

Influence of independent variables: Regression analysis. With an emphasis on the independent variables (age, gender, performance level / grade in geography, interest in the subject geography, interest in the topic desert, pre-instruction on deserts, extracurricular engagement with deserts, travel experience in desert areas,) with regard to their predictive strength for the subject-specific correctness of perceptions (all 43 items, if necessary recoded to "5" = subject-specifically correct) a multiple linear regression analysis (method: inclusion) was conducted.

In doing so, model 1 showed that the variable *desert was already a topic in the classroom* could predict 8.6% of the variance (see Table 8). If a second model additionally considers *extracurricular engagement with deserts*, a minimal rise of the value of the corrected R^2 to .88 is observable. In view of the very slight beta-weight of this second variable of .054 and the comparably high beta-weight of the variable *desert was already a topic in the classroom* of .293, *extracurricular engagement with deserts* can be neglected as a predictor. No other independent variables significantly contributed to an increase in the corrected R^2 value, or possessed only minimal beta-weights and therefore make no mentionable contribution to the predictive power. Summarized, only the variable *desert was already a topic in the classroom* possessed a predictive strength regarding the subject-specific correctness of perceptions. However, the explained variance of 8.6% is relatively low, and the effect size of $f^2 = .09$ is classified as small to moderate.

Table 8

Results of the Regression Analysis Relating To the Overall Scale of Students' Perceptions on Location and Formation of Deserts Regarding Subject-Specific Correctness (N = 585)

Model	*R*	*R²*	*Corr. R²*	*Standard deviation of the estimator*		*Significance of R^2*
1	.296[a]	.088	**.086**	.292	$F_{(1, 583)} = 56.01$	< .001
2	.302[b]	.091	**.088**	.292	$F_{(2, 572)} = 24.17$	< .001

a) Predictor: desert was already a topic in the classroom

b) Predictors: desert was already a topic in the classroom & extracurricular engagement with deserts

Independent variable: Desert was already a topic in the classroom. Against the background of the results from the regression analysis, the independent variable, whether deserts were already a topic in the geography classroom of the questioned students of the seventh grade, was of special interest. Four hundred forty-eight (76.7%) of the 585 students had not had instruction on deserts at the time of being surveyed, the other 137 (23.4%) students had been instructed on the topic desert within the previous weeks or months in the seventh grade geography classroom.

On the level of the sub-scale (approach 1), where all 43 items on location and formation were (re-)coded regarding the subject-specifical correctness and a total average value was calculated, significant differences showed in the average values (*MD* = 0.21, *t*(583) = -7.44, *p* < .001, Hedge's *g* = 0.73) between the students that had already had instruction on deserts (*n* = 137, *mean* = 3.37) and those that had not (*n* = 448, *MW* = 3.16). Therefore, a greater number of subject-specifically correct conceptions was found after instruction, and the given effect size implies that its practical relevance should be classified as high. On the level of the subscales *location* (22 items) or *formation* (21 items), significant group differences also emerged. Regarding the conceptions on *location*, students that had already had instruction on deserts (*mean* = 3.30) possessed a significantly greater number of correct conceptions (*MD* = 0.27, *t*(583) = -8,17, *p* < .001, Hedge's *g* = 0.79) than students without instruction (*mean* = 3.03). Concerning desert formation students with instructional experience (*mean* = 3.46) also showed a significantly greater number of correct conceptions (*MD* = 0.16, *t*(583) = -3,91, *p* < .001, Hedge's *g* = 0.38) than other students (*mean* = 3.30). The effect size of the mean value differences was high concerning the location, and moderate concerning formation.

On the level of the factor-analytically built subscales (approach 2), a single-factor MANOVA (Pillai's trace) showed significant differences in the mean values (*V* = 0.13, *F*(6, 578) = 14.56, *p* < .001, η^2 = .131), and further single-factor ANOVAs illustrated that for three out of six subscales, significant differences in the mean values between pre- and post-instructional conceptions existed (see Table 9). As to *the formation through wind* and *location of deserts in unbuilt areas with sand*, as well as *drought as an explanation for the formation and location of deserts*, no statistically meaningful differences between the groups emerged. The greater number of subject-specifically correct conceptions of students with instruction on the topic desert regarding the *formation through the sand of the sea* were rated to be of little practical relevance. However the subscales *location in the southern hemisphere or in the south* and *location at the equator* showed medium effect sizes: Students who had received instruction on the topic desert showed subject-specifically more correct conceptions in those areas. Students without previous instruction on deserts rated statements on the *location of deserts at the equator* not correct from a subject-specific perspective (*mean* = 2.42). On the other hand, the mean for students with instruction was 3.04. This shows, that students with instruction do not rate such statements subject-specifically incorrect anymore. The same applied for the conception *deserts are located in the southern hemisphere or far in the south*, which were rated more subject-specifically correct following instruction.

Table 9

Influence of the Independent Variable Desert Was Already a Topic in the Geography Classroom on the Empirical Subscale on the Preconceptions of Students Regarding Their Subject-Specific Correctness

	Desert was already a topic in the geography classroom *		*MD*	*F* (1, 583)	*p*	$\eta^2_{partial}$
	NO	YES				
Formation through the sand of the sea	3.15	3.48	0.33	16.15	.001	.027
Formation through wind	3.19	3.15	0.04	.23	ns	
Location in unbuilt areas with sand	3.20	3.34	0.14	2.73	ns	
Location in the southern hemisphere or the south	3.07	3.68	0.61	42.52	< .001	.068
Location at the equator	2.42	3.04	0.62	48.36	< .001	.077
Drought explains formation and location	3.62	3.48	0.14	3.18	ns	.007

* Mean value of agreement with own preconception (1 = not at all, 5 = completely); all items encoded in a way that "5" corresponds with the subject-specifically correct conception

An analysis of the subject-specific correctness of the preconceptions through weighting the subject-specifically correct and the subject-specifically incorrect items separated by location and formation regarding the independent variable *desert was already a topic in the geography classroom* (approach 3) showed significant mean value differences between the groups (single-factor MANOVA, $V = 0.12$, $F(4, 580) = 19.62$, $p < .001$, $\eta^2 = .119$). Following single-factor ANOVAs (see table 10) no strong differences in the mean value between students with or without instruction on the topic desert regarding the rating of subject-specifically correct statements were found. However, differences were found between the two groups concerning the everyday world or subject-specifically incorrect statements: The subject-specifically incorrect statements were rated as conforming to "own conception" significantly less after instruction had taken place. Even if it is a quasi-longitudinal study, the results imply that the above-mentioned higher subject-specific correctness of conceptions of students with instruction on the topic desert can be traced back to a reduction in the agreement with subject-specifically incorrect explanations.

Table 10

Influence of the Independent Variable Desert Was Already a Topic in the Geography Classroom on the Preconceptions of Students Regarding Their Subject-Specific Correctness

	Desert was already a topic in the geography classroom *		*MD*	*F* (1, 583)	*p*	$\eta^2_{partial}$
	NO	YES				
Subject-specifically correct statement on the formation	3.44	3.38	0.06	0.95	ns	
Subject-specifically correct statement on the location	3.02	3.03	0.01	0.05	ns	
Subject-specifically incorrect statement on the formation	2.73	2.52	0.21	18.53	< .001	0.031
Subject-specifically incorrect statement on the location	2.96	2.48	0.48	71.00	< .001	0.109

* Mean value of agreement with own preconception (1 = not at all, 5 = completely)

These results imply that either the formation of deserts is not – or hardly ever – thematized, or that instruction in that area is almost effectless. In contrast, the conceptions regarding the location of deserts seem to clearly shift to a greater numer of subject-specifically correct conceptions after instruction took place. A possible reason is that the landscape zone concept, in which the topic desert is embedded, goes along with the composition of a correct order pattern.

Separate analysis of pre- and post-instructional conceptions. In the face of the great importance of the factor whether deserts were already a topic in the geography classroom or not, the group of students with instruction (n = 137) and the group without instruction (n = 448) on the topic deserts were looked at separately and the differences between mean values of the subject-specific correctness of the preconceptions within both groups were examined. This analysis showed significant mean value differences within the students without instruction. Students that engaged with deserts outside the school context possessed subject-specifically more correct preconceptions than other students. The same applied for students with a great interest in geography in general, for students with a great interest in the topic desert, and for students with a very good or good general proficiency level. Significant mean value differences were also found regarding gender. In all cases the practical relevance was rather low due to low effect strengths. The group of students with instruction on the topic desert did not show any significant mean value differences regarding the independent variables. The results showed that in the pre-instructional phase, factors such as interest, extracurricular engagement with the topic etc.

were quite relevant for the subject-specific correctness of conceptions, albeit in a limited scope. These differences seem to even out through instruction.

The students' image of the desert as an independent variable. The independent variables showed little predictive power on the subject-specific correctness of preconceptions of location and formation of deserts with the exception of the variable *desert was already topic in the classroom*. At the same time, the mean value differences with regard to this variable were rather low. Therefore the focus was put on factors within a closer content-wise range to the conceptions of location and formation of deserts. Against this background the conceptions of the image of deserts, which were collected in Part A of the questionnaire (see Tab. 3), were analyzed as an independent variable regarding its influence on the subject-specific correctness of the conceptions of the location and formation of deserts. In order to do so, a dichotomization was carried out: One group had a clear conception of only sandy deserts (a), the other group (b+c) knew at least one other type of desert (b) or had a differentiated conception of deserts (c).

With reference to the full scale of subject-specific correctness that considered all 43 items on the formation and location (approach 1), *t*-tests for independent random samples showed significant mean value differences between students with a clear conception of sandy deserts (a) and those that possessed a more specialized conception (b and c). Students with a more specialized conception of the image of deserts (b and c) knew other types of deserts apart from sandy deserts and showed significantly more correct preconceptions on the location and formation of deserts (see Table 11). These differences showed medium effect sizes related to the full scale and the location of deserts.

Table 11
Subject-Specific Correctness of Preconceptions on the Level of the Full Scale with All Items, the Scale on Location And the Scale on Formation of Deserts with Subject to the Students' Image of Desert

	Students' Image of Desert*		*t* (562)	*p*	*g*
	(a) (n = 364)	(b) and (c) (n = 200)			
Full scale | location and formation of deserts (43 items)	*M* = 3.15 *SD* = 0.29	*M* = 3.30 *SD* = 0.30	-5.75	< .001	0.513
Sub-scale | location of deserts (22 items)	*M* = 3.02 *SD* = 0.33	*M* = 3.22 *SD* = 0.35	-6.86	< .001	0.614
Sub-scale | formation of deserts (21 items)	*M* = 3.30 *SD* = 0.40	*M* = 3.39 *SD* = 0.42	-2.51	.012	0.224

*Mean value of agreement with own preconception (1 = not at all, 5 = completely); all items encoded in a way that "5" corresponds with the subject-specifically correct conception

The level of the empirical built subscales (approach 2) also shows significant mean value differences (single-factor MANOVA, $V = 0.07$, F (6,557) = 6.96, $p < .001$,

η^2 = .070). Following ANOVAs reveal (see Table 12) that students with a clear sandy desert conception show subject-specifically less correct conceptions with regard to conceptions of *location of deserts in unbuilt areas with sand, on the southern hemisphere or in the south* as well as *on the equator*. The effect sizes are small to moderate with η^2_{partial}–values between .026 and .034. Regarding the formation of deserts through sand of the sea the mean values are uniform, the effect sizes however are small.

Table 12
Subject-specific Correctness of the Conceptions on the Level of the Empirically Built Subscales in Relation to the Students' Image of Desert

	Students' Image of Desert *		*MD*	*F* (1, 562)	*p*	η^2_{partial}
	(a)	(b) and (c)				
Formation through the sand of the sea	*M* = 3.17 *SD* = 0.83	*M* = 3.33 *SD* = 0.88	.16	4.72	.031	.008
Formation through wind	*M* = 3.18 *SD* = 0.92	*M* = 3.17 *SD* = 0.86	.01	0.02	ns	
Location in unbuilt areas with sand	*M* = 3.13 *SD* = 0.88	*M* = 3.42 *SD* = 0.79	.29	15.30	< .001	.026
Location in the southern hemisphere or the south	*M* = 3.08 *SD* = 0.98	*M* = 3.42 *SD* = 0.94	.34	16.14	< .001	.027
Location at the equator	*M* = 2.44 *SD* = 0.89	*M* = 2.80 *SD* = 1.00	.36	19.62	< . 001	.034
Drought explains formation and location	*M* = 3.61 *SD* = 0.81	*M* = 3.52 *SD* = 0.87	.09	1.66	ns	

*Mean value of agreement with own preconception (1 = not at all, 5 = completely); all items encoded in a way that "5" corresponds with the subject-specifically correct conception

An analysis of the subject-specifically correct and subject-specifically incorrect items showed significant mean value differences between students with a mere sandy desert image and students with a differentiated desert image (single-factor MANOVA, $V = 0.90$, $F(4, 559) = 13.85$, $p < .001$, $\eta^2 = .090$). Downstream ANOVAs showed that these differences did not exist relating to the subject-specifically correct items, but only in relation to subject-specifically incorrect items (see Table 13). Students that possessed a differentiated desert image had fewer misconceptions about the formation and location of deserts than students with a mere image of a sandy desert. The effect size regarding the formation was classified as small to moderate; regarding location, the effect size was moderate.

Table 13
Subject-specific Correctness of the Preconceptions on the Level of the Subject-specifically Correct and the Subject-specifically Incorrect Items on the Location and Formation of Deserts in Relation to the Students' Image of Desert

	Students' Image of Desert *		*MD*	*F* (1, 562)	*p*	$\eta^2_{partial}$
	a	b) / c)				
Subject-specifically correct statements on formation	*M* = 3.44 *SD* = 0.67	*M* = 3.40 *SD* = 0.68	.04	0.51	ns	
Subject-specifically correct statements on location	*M* = 3.01 *SD* = 0.43	*M* = 3.02 *SD* = 0.51	.01	0.06	ns	
Subject-specifically incorrect statements on formation	*M* = 2.73 *SD* = 0.49	*M* = 2.61 *SD* = 0.55	.12	7.60	.006	.013
Subject-specifically incorrect statements on location	*M* = 2.98 *SD* = 0.58	*M* = 2.61 *SD* = 0.62	.37	50.85	< .000	.083

* Mean value of agreement with own preconception (1 = not at all, 5 = completely)

The three analyses of the connections between subject-specifical correctness of the conception and the conceptions of the appearance of deserts resulted in the central finding that students with a differentiated desert image also possessed more subject-specifically correct conceptions, especially of the desert location. It additionally showed that the subject-specifically more correct conceptions could be primarily traced back to a reduction in misconceptions, especially in the location of deserts.

At the same time, it is important to keep in mind that the direction of the connection remains unclear and could be plausible in either direction. The revealing of this connection is of great importance for instructional purposes: The fact that students possess perceptions about deserts as mere sandy deserts at the beginning of a teaching sequence gives the teacher the indication that those students also possess more subject-specifically incorrect conceptions of the location and (partly) of the formation of deserts.

Conclusion and Discussion

In the following section the central results from the open Part A of the questionnaire and the item-based Part B will be compared, summed up and set in relation to the current state of research. Additionally, their meaning is discussed and a view on future research is given.

Location of Desert Areas – Comparison between Part A und B

In order to compare both parts of the questionnaire, it is important to note that within the closed Part B a constant connection between location description and the reasons for

that location was given, and neither concrete regions nor continents were collected systematically. Therefore the results can only be compared indirectly. Nonetheless, some central correspondences can be found in both parts. Within the preconceptions collected in Part A, drought or the absence of water were of great importance (see Table 6). That same factor is also of central relevance in Part B and the subscale *location and formation explained through drought* reached the highest mean value in subject-specific correctness (see Table 9); also, those single items with reference to drought occupy position 1, 2 and 4. Regarding the equator, both parts of the questionnaire showed similar results again. It is therefore possible to speak about great correspondences between the open (Part A) and closed (Part B) sections of the questionnaire regarding the preconceptions of the desert location.

Formation of Deserts – Comparison between Part A und B

Drought as a subject-specifically correct explanation for the formation of deserts was mentioned most in the open Part A of the questionnaire. Correspondingly, the subscale *location and formation explained through drought* reached the highest mean value in subject-specific correctness in the item-based Part B. The same applied for the single item scale on which items on the formation through drought showed the highest level of correspondence with own conception. Other parts also showed numerous correspondences between the open and the closed parts of the questionnaire. It is important however that, especially with regard to wind and sea as a reason for desert formation, the rating on the single item scale is very different in each case. The preconceptions of the students obviously showed general, basic conceptional categories (e.g. deserts form through wind). The differentiation of these categories turned out to be very different however, resulting in items in the same conceptional category being rated differently with regard to their correspondence with own preconceptions. Students also used these detailed differentiations in the open part of the questionnaire, but due to the encoding and the resulting generalizations they were not visible in the results. Nonetheless, the different methodical accesses show similar results within their own explanatory power and are therefore generally useful for identifying conceptions that occur relatively frequently.

Comparison between Results of the Study and Current State of Research

Part A. A comparison of the results with those of the qualitative interview study (cf. Schubert 2012, 2014) shows that the encodings of the students' answers on the open questions in Part A are almost identical to the conception categories of the interviews. With regard to content, the interview study could not identify some of the conceptions, but nonetheless the frequencies were within a single-digit range in each case which, given the overall scope of $N = 585$ samples, illustrates that those perceptions are rare or singular. At the same time, results show that the conceptions identified through the interview study were found with different frequencies. Against the background of these results it becomes clear that the open Part A of the questionnaire could, on the one hand, be used as a validation of the qualitative results and a confirmation as far as possible. On the other hand, it is possible to estimate which conceptions are likely to be found relatively frequently and which relatively rarely on the basis of these results. Therefore the open part of the questionnaire offers an expansion of the qualitative results with regards to content.

Part B. The conceptional categories of the location and formation of deserts identified through the interview study were presented in the form of statements within the item-based Part B and were in turn formulated close to the actual student answers in the interviews. Therefore, no new and previously unidentified conceptions were identified in this part. The item-based survey nonetheless enabled a quantification of the preconceptions found in the interview study and implied certain factors of influence. With regard to content, a similar frequency of preconceptions as in the open questions (Part A) was found. At the same time, the requested evaluation of correspondence with own conceptions highlighted that the different conceptions were distributed heterogeneously among the students. Thus, items that were generally (in terms of mean values) rated high in their correspondence with own conceptions, were also rated as corresponding "rarely" or "not at all" by a significant number of students. All in all, the item-based questioning of students contributed to the quantification of the collected preconceptions through the qualitative interview study and, at the same time, illustrated the broad spectrum or great heterogenity of the existing preconceptions.

Future Research

With reference to other studies, the conception and evaluation of teaching material that explicitly includes prominent student conceptions seems to be the next logical step. Within this context, differences between pre- and post-instructional conceptions could be systematically analyzed through a longitudinal section or with focus on learning paths. Furthermore, the investigation should be expanded to include other groups, with special interest in the conceptions of teachers. The existing data of the just presented variable-centered analysis could additionally be analyzed in a person-centered approach. By doing so, possible existing conception patterns could be identified. At a more general level, the question arises whether there are other independent variables with more predictive power than the ones included in this questionnaire or whether the conceptions are really that heterogeneous, without any correlation regarding gender, interest etc.

References

Adamina, M. (2008). *Vorstellungen von Schülerinnen und Schülern zu raum-, zeit- und geschichtsbezogenen Themen. Eine explorative Studie in Klassen des 1., 3., 5. und 7. Schuljahres im Kanton Bern* [Preconceptions of students on space-, time- and history-related topics. An exploratory study in classes 1, 3, 5 and 7 in the Canton of Bern]. Muenster: University of Muenster.

Bortz, J., & Döring, N. (2006). *Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler* [Research methods and evaluation for human and social scientists]. Heidelberg: Springer.

Böwing-Schmalenbrock, M., & Jurczok, A. (2012). *Multiple Imputation in der Praxis: Ein sozialwissenschaftliches Anwendungsbeispiel* [Multiple imputation in practice: An example of application from social science]. Online via: URN urn:nbn:de:kobv:517-opus-58111.

Bühner, M. (Ed.) (2006). *Einführung in die Test- und Fragebogenkonstruktion* [Introduction to the construction of tests and questionnaires]. München: Pearson.

Dove, J. (1999). *Theory into practice. Immaculate misconceptions*. Sheffield: Geographical Association.

Duit, R. (2006). Schülervorstellungen und Lernen von Physik – Forschungsergebnisse und die Realität der Unterrichtspraxis [Student's preconceptions and learning of Physics – research results and the reality of teaching practice] . In R. Girwidz, M. Gläser-Zikuda, M. Laukenmann, & T. Rubitzko (Eds.), *Lernen im Physikunterricht. Festschrift für Prof. Dr. Christoph von Rhöneck* [Learning in Physics lessons. Commemorative publication for Prof. Dr. Christoph von Rhöneck] (pp. 13–22). Hamburg: Verlag Dr. Kovac.

Duit, R. (2010). Schülervorstellungen und Lernen von Physik [Student's preconceptions and learning of Physics]. In PIKO-Brief (1) Online via: http://www.ipn.uni-kiel.de/projekte/piko/pikobriefe032010.pdf.

Gerstenmaier, J., & Mandl, H. (1995). Wissenserwerb unter konstruktivistischer Perspektive [Knowledge acquisition from a constructivst perspective]. *Zeitschrift für Pädagogik*, 41(6), pp. 867–888.

Gropengießer, H. (2007). *Didaktische Rekonstruktion des Sehens. Wissenschaftliche Theorien und die Sicht der Schüler in der Perspektive der Vermittlung* [Didactical reconstruction of seeing. Scientific theories and the view of students on the perspective of mediation]. Oldenburg: Didaktisches Zentrum Carl von Ossietzky Universität Oldenburg.

Gropengießer, H. (2010). Biologie unterrichten [Teaching biology]. In J. Markl (Ed.), *Markl Biologie - Lehrbuch Oberstufe* [Markl biology – course book senior classes] (pp. 5–82). Stuttgart: Klett.

Helmke, A., & Schrader, F. (2010). Determinanten der Schulleistung [Determinants of school perfomance] In D. H. Rost (Ed.), *Handwörterbuch Pädagogische Psychologie* [Pocket dictionary educational psychology] (pp. 90–102). Weinheim, Basel: Beltz.

Johannsen, M., & Krüger, D. (2005). Schülervorstellungen zur Evolution – eine quantitative Studie [Student's preconceptions on evolution – a quantitative study]. *Berichte des Institutes für Didaktik der Biologie der Westfälischen Wilhelms-Universität Münster* [Chronicles of the Institue of Didactics of Biology at the Westphalian Wilhelms-University Münster], 14, pp. 23–48.

Jonas, C., Riemeier, T., & Krüger, D. (2004). Häufigkeit von Lernervorstellungen zur Zellteilung [Frequency of learner's preconceptions on cell division]. *Erkenntnisweg Biologiedidaktik* 3, pp. 79–94.

Lienert, G. A., & Raatz, U. (Eds.) (1998). *Testaufbau und Testanalyse* [Test setup and test analysis]. Weinheim: Beltz.

Ministerium für Schule und Weiterbildung des Landes Nordrhein-Westfalen (Ed.). (2008). *Kernlehrplan für das Gymnasium – Sekundarstufe I in Nordrhein-Westfalen. Biologie* [Core curriculum for German secondary schools – secondary level I in Northrhine-Westphalia. Biology]. Frechen: Ritterbach Verlag.

Mohn, A. (2015). Das Interesse von Schülerinnen und Schülern am Thema Wüste [Student's interests on the topic desert]. In J. C. Schubert & K. Wrenger, (Eds.), *Wüsten und Desertifikation im Geographieunterricht. Empirische Studien zu Vorstellungen und Interessen von Schülerinnen und Schülern* [Deserts and desertification in Geography lessons. Empirical studies on the preconceptions and interests of students] (pp. 265-295). Münster: Monsenstein-und Vannerdat-Verlag.

Moosbrugger, H., & Kelava, A. (Eds.) (2012). *Testtheorie und Fragebogenkonstruktion* [Test theory and questionnaire construction]. Berlin, Heidelberg: Springer-Verlag.

Newman, D. A. (2014). Missing data: Five practical guidelines. *Organizational Research Methods*, 17(4), pp. 372–411.

Niedderer, H., & Schecker, H. (1992). Towards an explicit description of cognitive systems for research in physics learning. In R. Duit, F. M. Goldberg, & H. Niedderer, (Eds.), *Research in physics learning: Theoretical issues and empirical studies; proceedings of an international workshop* (pp. 74–98). Kiel: IPN.

Peugh, J. L., & Enders, C. K. (2004). Missing data in educational research: A review of reporting practices and suggestions for improvement. *Review of Educational Research*, 74(4), pp. 525–556.

Prüfer, P., & Rexroth, M. (2000). Zwei-Phasen-Pretesting [Pretesting in two stages]. *ZUMA-Arbeitsbericht*, 8, pp. 1–21.

Reinfried, S. (2007). Alltagsvorstellungen und Lernen im Fach Geographie. Zur Bedeutung der konstruktivistischen Lehr-Lern-Theorie am Beispiel des Conceptual Change [Everyday preconceptions and learning in Geography. On the importance of the constructivist teaching and learning theory by the example of conceptual change]. *Geographie und Schule* 29(168), pp. 19–28.

Reinmann, G., & Mandl, H. (2006). Unterrichten und Lernumgebung gestalten [Teaching and the development of learning environments]. In A. Krapp, & B. Weidenmann (Eds.), *Pädagogische Psychologie*. *Ein Lehrbuch* [Educational psychology. A course book] (pp. 613-658). Basel: Weinheim.

Riemeier, T. (2007). Moderater Konstruktivismus [Moderate constructivism]. In D. Krüger, & H. Vogt (Ed.), *Theorien in der biologiedidaktischen Forschung – Ein Handbuch für Lehramtsstudenten und Doktoranden* [Theories in the research of the didactis of Biology – a handbook for students of teaching and PhD students] (pp. 69–79). Berlin, Heidelberg: Springer-Verlag.

Rubin, D. B. (Ed.) (1987). *Multiple imputation for nonresponse in surveys*. New York: Wiley & Sons.

Schafer, J. L., & Olsen, M. K. (1998). Multiple imputation for multivariate missing-data problems: A data analyst's perspective. *Multivariate Behavioral Research*, *33*(4), pp. 545–571.

Schubert, J. C. (2012). *Schülervorstellungen zu Wüsten und Desertifikation – Eine empirische Untersuchung zu einem zentralen Thema des Geographieunterrichts* [Students' conceptions on the topic of deserts and desertification – An empirical research project on a crucial topic of geography classrooms]. Muenster: University of Muenster.

Schubert, J. C. (2014). Students' preconceptions of the formation and location of deserts. Results of a qualitative interview study with grade 7 students in Germany. *Review of International Geographical Education Online,* 4(2), pp. 102–119.

Schubert, J.C. (2015): Causes, processes and consequences of "desertification": Results of a qualitative study about the conceptions of 12- and 13-year-old students in Germany. *International Research in Geographical and Environmental Education*, DOI: 10.1080/10382046.2014.993172.

Van Ginkel, J. R. & Kroonenberg, P. M. (2014). Analysis of variance of multiply imputed data. *Multivariate Behavioral Research,* 49(1), pp. 78–91.

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