J-READING
JOURNAL OF RESEARCH AND DIDACTICS IN GEOGRAPHY
2, 11, December, 2022, pp. 15-34 DOI: 10.4458/5598-02

Teacher students' beliefs about and strategies for dealing with students' misconceptions

Kathrin Schulman[a], Marko Demantowsky[b]
[a] School of Education, University of Applied Sciences and Arts Northwestern Switzerland, Windisch, Switzerland
[b] Faculty Center for Transdisciplinary Historical and Cultural Studies, University of Vienna, Vienna, Austria
Email: kathrin.schulman@fhnw.ch

Received: July 2022 – Accepted: October 2022

Abstract

Misconceptions impact learning and behavior. Students' misconceptions are often persistent. But research has shown that some strategies of dealing with them are more likely to lead to conceptual change than others. Thus, it is important for teachers that they can notice students' misconceptions and then use evidence-based strategies to deal with them. This study uses data from online questionnaires. Data was collected in the German speaking area of Switzerland. The sample consists of geography and/or RZG teacher students for secondary school that had already taught in school (n=83). RZG is a subject similar to social studies.
The results show that the majority of participants saw themselves as constructivist. Yet, a considerable share said they had not noticed any misconceptions in their students. Of those who did, a large share did not describe any strategy how they dealt with them. Among those who described a strategy, evidence-based strategies were rare. Some were not even mentioned once. Thus, it seems that conceptual change research does not impact the practice of many teacher students. Teacher students need to learn more about evidence-based conceptual change strategies and how to apply them to their practice. More research is needed on how to more effectively help them to do so.

Keywords: Misconceptions, Teacher Beliefs, Teacher Practices, Conceptual Change Strategies, Evidence-Based Geography Education, Secondary School Teachers

1. Introduction

People's geographic misconceptions can have a profound effect if they are not changed. For instance, people with misconceptions about climate change are often less inclined to adopt more climate friendly behaviors (e.g., Kácha et al., 2022; Seroussi et al., 2019). They also could be more likely to vote in a way that impedes climate friendly policies, especially in a system with a strong direct democracy component like Switzerland. Thus, misconceptions can contribute to earth-scale, serious problems.

Students often have misconceptions about geographic topics and areas (e.g., Schulman et

al., 2020). Many studies about students' conceptions in geography have been published (e.g., Reinfried and Schuler, 2009). Yet, "a number of topics/regions relevant to […the curriculum] are not yet sufficiently covered" (Schulman et al., 2020, p. 15, translated).

Students' misconceptions are often persistent throughout their time at school. For instance, an Israeli study (Ben-Zvi Assaraf and Orion, 2005, p. 371) showed

> […] that most […] students enter junior high school with a partial and fragmented conception of the water cycle and graduate from it with almost the same misunderstandings. This finding is surprising since water is a central issue in Israel's science curricula at the elementary school and junior high levels.

Studies about students' conceptions of Africa in Switzerland and Germany also showed that similar limited conceptions exist across grades (e.g., Adamina, 2008; Knauer, 2013). More generally, as a literature review by Thomm et al. (2021, p. 1056) argued, people "tend to discount, reinterpret, or ignore the evidence rather than revise their own assumptions" when a new information is not in line with their own beliefs.

Students' conceptions play a crucial role in learning and teaching (e.g., Groß et al., 2019; Renkl, 2000). Based on research in science education "instruction is most effective when it is informed by an understanding of the common alternative conceptions that students hold in specific topic areas (Park and Oliver, 2008)" (Lane, 2015, p. 44). Prior conceptions can provide an anchor for new information, and thus facilitate learning, but misconceptions can also hinder learning (Lane, 2015; Renkl, 2000). Conceptions are also closely related to systems thinking (e.g., Jahn et al., 2015; Rempfler, 2010; Viehrig and Rinschede, 2020; Viehrig and Siegmund, 2018), a central objective of geography education (DGfG, 2012; Viehrig, 2015). Therefore, knowing students' misconceptions as well as conceptual change strategies is an important part of teachers' pedagogical content knowledge (PCK) (e.g., Cochran, 1997; Shulman, 1986, 2015).

Students say their conceptions come from a variety of sources (Table 1). Even if they do not agree to certain misconceptions themselves, students encounter them in their everyday lives. For example, a study in Switzerland asked students from where they knew climate change related fake news and conspiracy theories, no matter whether they personally agreed with that conception or not. 28% of the students knew them from "social media (Instagram, WhatsApp, Telegram, Snapchat, Pinterest)", 23% from "friends, acquaintances, family", 18% from "newspapers, TV, books, magazines", 16% from "YouTube channels", and 15% from "school/teachers" (Schreier, 2021, p. 68, translated).

2. Teachers' knowledge about students' misconceptions

Many teachers do not have a good PCK. A study in Germany, for instance, showed that "irrespective of work experience, the topic of student conceptions is not yet an integral part of the geography education related professional knowledge of geography teachers" and their conceptions about student conceptions were insufficient to "design constructivist learning environments" (Barthmann et al., 2019, p. 92, translated). Similarly, an Australian study showed that only four of the 16 geography teachers studied were "able to provide rich, detailed and specific examples of students' common alternative conceptions and areas of difficulty" (Lane, 2015, p. 49). 12 of 16 teachers "did not see any value in exploring students' existing conceptions or encouraging students to question or where necessary, restructure these beliefs" (ibid., p. 54).

Teachers' own misconceptions also play a crucial role. Teachers/teacher students often have geographic misconceptions (e.g., Hannah and Rhubart, 2019; Lane, 2009; Lane and Catling, 2016; Nas and Çalık, 2018; Reinfried, 2006; Reinfried and Künzle, 2019; Seroussi et al., 2019). Teachers can pass on their misconceptions to their students (see e.g., Nas and Çalık, 2018; literature reviews in Preston, 2015; Yates and Marek, 2014). Teachers' misconceptions can also cause them to not notice students' misconceptions. In a study in Germany, pre-service teachers made counterfactual comments, which often "refer[ed] to incidents in the vignette where students made geographical content mistakes but the participant explicitly stated that there was no mistake" (Scholten and Sprenger, 2020, p. 210). Additionally, teacher conceptions and beliefs also impact their teaching practices (e.g., Hannah and Rhubart, 2019; Lane, 2009).

Concept investigated	Study (n)	media	family	school	peers	other
1. groundwater	Reinfried (2007, p. 28) (n_{class1}=19, n_{class2}=23)	books: 31.6%/ 34.8% TV: 10.5%/ 21.8%	parents: 42.1%/ 43.5%	31.6%/ 43.5%		
2. poverty in Switzerland	Friedli (2019, p. 59) in Schulman et al. (2020) (n=42)	TV: 45.2% newspapers/magazines: 11.9% internet 9.5% mobile phone: 7.1%	parents: 54.8%	28.6%	friends: 14.3%	19%
3. India	Chatziioannidis (2018, p. 199) in Schulman et al. (2020) (n=31)	TV/news: 25.8% movies: 12.9% documentaries: 9.7% newspaper: 6.5% internet (YouTube): 6.5% books 6.5% pictures: 3.2% radio: 3.2%	parents/ siblings/ relatives: 12.9%	9.7%		heard: 9.7% general knowledge: 3.2% no idea/no answer: 19.4%
4. tourism in Switzerland	Heiniger (2019, p. 53) in Schulman et al. (2020) (n=235)	internet: 57.4% TV: 53.6% newspapers/magazines: 31.9%	parents: 54.5%	39.1%	friends: 28.9%	own experiences as tourist: 37.9% other: 9.4%
5. Israel	Avci (2021, pp. 62-64) (n=85)	71.76%	22.35%	42.35%	acquaintances: 14.12%	12.94%
6. Balkan	Shabani-Gashi (2020, p. 105) (n=100)	books: 1% internet: 3% media: 1% presentation(s): 2% song: 1%	9% "home or so": 1%	5%	43% soccer: 1% specific name:1%	no answer/no idea/nowhere /guessed/no knowledge etc.: 31% being Albanian or from Kosovo 5% holidays: 2% other: 4%
7. poverty	von Burg (2020, p. 61) (n=49)	movie/series/TV: 61.2% ads: 4.1% newspaper: 16.3% news: 4.1% internet: 10.2% radio: 10.2% documentaries: 10.2% book: 12.2%: YouTube: 4.1%	parents: 14.3%			experiences: 12.2%:
8. climate change	Adamina et al. (2018, p. 108) (n=62)	"media: newspaper, TV, radio, YouTube, social media": 45.2% books: 3.0% ads: 1.2%	"parents, acquaintances": 12.7%	33.1%		"other sources (e.g. political actions)": 4.2%

Table 1. Overview of some studies in Switzerland regarding sources for students' conceptions.
(Usually more than one answer possible; studies 1-7 percentage of students, study 8 percentage of all answers given; all translated).

3. Noticing misconceptions

Without noticing misconceptions, teachers cannot address them. Teachers can design activities to get to know their students' conceptions. For that, the same methods as in conception research can be used, such as true/false questions (e.g., Reinfried, 2007), multiple choice questions (e.g., Lane, 2009), mental maps (e.g., Murtaj-Zeneli, 2019; Obermaier and Schrüfer, 2009), drawings (e.g., Reinfried, 2007), or oral ques-

tions/discussions with or without prompts (e.g., Barthmann et al., 2019; Lane, 2009). Teachers can also notice misconceptions e.g. in classroom discussions, in student answers when solving tasks, or in student questions (e.g., Lane, 2009).

4. Evidence-based strategies for dealing with students' misconceptions

After teachers notice misconceptions, what can they do to change them? Research has identified several strategies that support conceptual change (see below), although more research is needed. Additionally, theoretical models and factors that support conceptual change have been suggested (e.g., Hashweh, 1996; Krüger, 2007).

4.1 Strategy 1: Observation of natural phenomena

A systematic review of conceptual change approaches in earth science/astronomy described several studies that showed that observing natural phenomena can lead to successful conceptual change for most students (Mills et al., 2016). In a study in the U.S. (Giamellaro, 2015), being "immersed for multiple days or weeks in an environment that was the focus of their studies" (p. 13) as part of ecology classes led to a significant improvement. Students that had conceptual change "were also able to articulate their conceptual change process", but "some student [sic] did not show significant change" (p. 14).

4.2 Strategy 2: Confronting students with authentic media or people

Schrüfer (2003) examined the effects of a unit focused on intercultural learning, which included, among others, materials from Schmidt-Wulffen (1999). These materials featured the response of students from Ghana to the (mis)conceptions of German students about Ghana. There was a significant difference in the pre-to-post-test change in understanding foreign peoples between the treatment and control group in the intended direction. The students in the treatment group also showed more differentiated answers in the open questions in the post test. In the control group there was no change.

When possible, another option is to invite people from the respective group. In a Swiss study, German and math teachers' biased expectations against students with migration background were reduced through an intervention that included e.g., information, role-play, reflection, classroom implementation, discussion, and visits by "adults who grew up in low-SES families or with migration backgrounds who had attained higher educational levels than their parents had" (Neuenschwander et al., 2021, p. 4).

4.3 Strategy 3: Models, experiments, and simulations

The systematic review by Mills et al. (2016) described several studies that showed physical models and simulations were effective for conceptual change. Models were also part of the strategies used by an experienced geography teacher in Lane's Australian (2009) study, which based on observations seemed to help the students. Similarly, based on the observations of one Australian geography pre-service teacher in Reitano and Harte (2016)'s study, using double-filled Oreo cookies helped students understand plate tectonics. Brockmüller and Siegmund (2020) showed that models helped students significantly improve their systemic thinking pre-to-post-test. The combination of digital and hands-on models was significantly better than just digital models alone. Students in the hands-on models only group improved a bit more than those in the digital models only group, but the difference was not significant.

An extension of working with models are so-called "slowmations". The systematic review by Mills et al. (2016) describes how learners create stop-motion animations from manipulating and photographing models. Mills et al. (2016) describe that Nielsen and Hoban (2015) found this method to be effective for conceptual change.

In a study by Reinfried et al. (2010), both the traditional learning materials and the conceptual change learning materials contained worksheets and an experiment, yet the conceptual change learning materials led to a better student under-

standing. This suggests that the way experiments/models are integrated into lessons might play a big role in how effective they are.

Moreover, students' general experimentation skills also play a role. A study with elementary students in Switzerland showed that "understanding of the control-of-variables strategy predicts […] content knowledge development from before to after instruction" (Edelsbrunner et al., 2018, p. 38). The study used a "guided-inquiry based instruction on floating and sinking" that included hands-on experiments (ibid.).

However, some models/experiments can actually foster misconceptions instead of changing them (e.g., Linfield and Holbrey, 2021).

4.4 Strategy 4: Conceptual change texts/refutational texts

Egbers and Marohn (2013, p. 121, translated) suggest the following structure for conceptual change texts:

1. describing the question/issue;
2. "present[ing…] alternative conceptions";
3. "refut[ing … these] alternative conceptions";
4. "making [this refutation] plausible through examples";
5. "present[ing…the] scientifically accepted conceptions";
6. applying and comparing one's conception now to one's conception at the beginning.

Another structure is (Chambers and Andre, 1995):

1. activation of pre-conceptions,
2. alternative conceptions and their refutations,
3. introduction of the scientific conception.

Other variants also exist (Grospietsch and Mayer, 2021).

Research in science education showed that conceptual change texts lead to better student understanding than traditional (textbook) texts (e.g., Beerenwinkel, 2006; Chambers and Andre, 1995; Chambers and Andre, 1997). In a study on air pressure in Turkey, "conceptual change texts and concept maps" led to better understanding than "traditional teaching methods" (Akbas and Genctürk, 2011, p. 2217). A study with teacher students in Germany showed that a course with conceptual change texts led to a significant decrease in agreement to neuromyths overall, but conceptual change differed between the different misconceptions (Grospietsch and Mayer, 2021). In their systematic review, Mills et al. (2016) describe four studies about "refutation texts". They only describe the results of one (Broughton et al. 2013), which showed that the texts led to significant conceptual change. McCuin et al. (2014), in a study with university students in the U.S., compared instruction with a traditional text to that with a text "that addresses both the correct scientific concepts and the associated misconceptions" (p. 447). Part of the text was in common. Both groups improved significantly. There were no significant differences between the two groups in improvement pre-to-post-test. However, pre-test-to-delayed-post-test "gains in performance […] were significantly larger" for the misconception group than for the traditional group (p. 452).

4.5 Strategy 5: Analogies

The systematic review by Mills et al. (2016) described two studies which showed that known analogies can help students to "construct scientific conceptions" (p. 779). Analogies were also part of the strategies used by an experienced geography teacher in Lane's (2009) study, which based on observations seemed to help the students. Similarly, Reitano and Harte (2016) featured one pre-service geography teacher who described how using the analogy of a rubber band (and a rope experiment) helped students understand earthquake waves.

4.6 Strategy 6: Concept cartoons

Concept cartoons are often used to find out more about students' conceptions (e.g., Keogh and Naylor, 1999; Serttaş and Yenilmez Türkoğlu, 2020). However, they can also be used as a conceptual change strategy (e.g., Naylor and Keogh, 2013). For instance, in a study with pre-service teacher students in Turkey (Taşlıdere, 2013), one group worked with concept cartoon worksheets, while the other used "traditional instruction" (p. 144). Students in the concept cartoon group performed significantly better than in the traditional group.

4.7 Strategy 7: Conceptual change learning environments

Conceptual change learning environments can be very different, depending on the study. Because they combine different activities, it can be hard to clearly state whether any positive effect is due to the combination of activities or due to any one component.

Reinfried et al. (2010), in a study in Switzerland, showed that conceptual change learning materials helped eighth graders understand the greenhouse effect better than traditional learning materials. The conceptual change materials had worksheets that e.g., "start[ed] from undifferentiated pre-knowledge/everyday conceptions", use reduced information and few specialist terms (p. 258, translated). They also included an experiment. The traditional group also worked with a (different) experiment. Their worksheets were based on standard school textbooks.

Reinfried et al. (2013), in a study in Switzerland, used a learning environment which included e.g., guided inquiry, analogies, and experiments/models. The worksheet started with "activating pre-knowledge" (p. 268, translated). The materials helped students make significant knowledge gains about springs. The control group did not have any instruction about springs.

Reinfried and Tempelmann (2014), in a study with seventh graders in Switzerland, used e.g., drawings of students' conceptions and an intervention with a worksheet and experiment. They showed that the success of conceptual change learning materials depended on students' conceptions: both those with little previous knowledge and those with conceptions "that correspond[ed] to the fundamental ideas of the target model" (p. 31, translated) achieved the target model or got very close. In contrast, those with conceptions that "for them ha[d] a higher explanatory value than the information conveyed in the classroom, d[id] not change their mental models successfully" (p. 31, translated).

In a study with teacher students in Germany (Reinfried, 2006), one group was taught based on the strategy's developed by Taylor et al. (2003). It consisted of a (1) pre-test, (2) "articulat[ing] and compar[ing] their prior mental models within their groups and within class" (p. 47), (3) "[u]s[ing] a real scientific model to understand how it works" and "[c]ompar[ing] it with their own conceptions" (p. 47), (4) using the new conception "to solve problems" (p. 47) and "[r]eflection" (p. 47). The group used a groundwater model and experiments. The control group used an oral teacher presentation of the right conception "using the transparencies or making drawings on the backboard [*sic*], asking or answering students' questions" (p. 48). The first group had "fewer misconceptions […] about groundwater than did the control group" "[a]fter the intervention" (p. 41).

A Swiss study (Reinfried, 2007) with eighth graders compared a constructivist approach (model building; less structured learning environment, using e.g., drawing their mental model, and working with a groundwater model and experiments) and a cognitive approach (guided instruction; highly guided learning environment, using e.g., a self-evaluation test, a learning task, presentation of some results, and a writing task) for learning about groundwater. Both led to significant conceptual change, with no statistical difference between the two approaches.

Martínez et al. (2012), in a study with elementary students in the U.S., found that a "science and reading intervention" (p. 54), using e.g., "a Web-based system called GoInquire" (p. 57), reciprocal teaching (e.g., self-monitoring) and a field trip was successful at significantly reducing four out of eleven identified misconceptions about water erosion.

A study in Ghana (Kumi-Manu, 2021) used a learning environment using concept cartoons, "hands-on activities and group discussions" (p. 594), experiment, "teacher-led instruction" (p. 595), "compar[ing] their newly structured ideas with those presented by the researcher" (p. 595), applying the concepts, and evaluating their learning progress. The paper concludes that that "enabled the pupils to correct their misconceptions" (p. 587), without describing concrete data.

A science study with nineth graders in Turkey (Atasoy and Ergin, 2016) used worksheets that included concept cartoons, hands-on or minds-on activities, and an application. The control group used a traditional approach with e.g., "presentation, question–answer, procedural problem solving" (p. 61). The conceptual change group had a significantly higher post-test score

than the traditional group. Interviews showed that most students in the traditional group still had the same misconceptions. In the conceptual change group only a minority of students kept some of their misconceptions.

4.8 Knowing multiple strategies

As this review of evidence-based strategies showed, often one strategy does not work to change the misconceptions of all learners, or to change all their misconceptions. Consequently, it is important that teachers know multiple strategies for conceptual change.

5. Relationship between strategies and teachers' beliefs

Constructivist beliefs can lead to more effective conceptual change practices. For instance, Hashweh (1996), in a study in the West Bank, found that empiricist teachers used "explain", which was judged as not efficient for conceptual change, more often than constructivists. Constructivists used strategies described as more effective for conceptual change such as the "restructure" or "refute" strategy more than empiricists. The constructivist group also had more teachers using multiple strategies than the empiricist group. Moreover, "constructivists tended to rate the more effective strategies as more important compared to the empiricist" (p. 59).

In contrast, a study with U.S. physics faculty found that on a scale from traditional (transmissionist) to alternative (constructivist), "every instructor was rated as more alternative on the conceptions scale than on the practices scale" (Henderson and Dancy, 2007, pp. 2-5). Moreover, while "[n]one exhibited conceptions purely or even mostly consistent with traditional instruction […] three of the instructors had a majority of self-described teaching activities consistent with traditional practices" (ibid.). Thus, just because one has constructivist beliefs does not necessarily mean that one's practices are also constructivist.

6. Method

6.1. Research questions

The overall question addressed in this paper is: Do teacher students have beliefs and practices that support conceptual change in their students?

Based on the literature review, this question is broken down into the following research questions:

1. Do participants see themselves as constructivist?
2. Do participants in general use practices such as student-oriented methods, differentiated learning or planning their lesson based on the group of learners they are teaching that could be seen as indicators of a rather constructivist practice?
3. Are participants aware of sources of students' conceptions?
4. Do participants notice students' misconceptions?
5. If participants notice students' misconceptions, do they use evidence-based strategies to address them?

For all five questions, differences between participants will be tested based on:

a. their usage of specialist literature and knowledge of empirical studies as a direct indicator of engaging with scientific literature
b. their interest in geography and history didaktics[1] as an indirect indicator of scientific literature engagement
c. their migration background.

For questions 2-5, differences are also tested between:

d. constructivist vs. transmissionist participants.

6.2. The #TCDTE Project

The interdisciplinary #TCDTE ("Teachers' concepts of digital tools in education") pilot project had several phases. This paper uses data from that was collected from May 2017 to March 2019. We used online questionnaires that

[1] Didaktics is spelled with a k based on a suggestion by Brooks (2016) to differentiate the central European meaning from the one commonly associated with it in English-speaking countries (see e.g., Viehrig et al., 2019).

were implemented in Questback. The questionnaires were in German. The questionnaires were developed over time. The different versions used for this paper are labelled by using Q (for questionnaire) and a number.

The questionnaires covered many different areas, such as interests, teaching practices, conceptions, and knowledge of research. Only the items relevant to this paper are reported here, translated into English. Participants' answers have also been translated throughout.

The data was exported to SPSS. The data from the different questionnaire versions was combined into one file. The open-ended question about misconception strategies was checked against the html export and any cut-off part of the answer was added to the SPSS file. Group differences are evaluated at the p=0.05 level.

6.3. Sample

"The #TCDTE project targeted teachers and teacher students. Participants were recruited in classes for teacher students and through messages at one institution as well as through emails and contacts" (Schulman and Demantowsky, submitted).

After excluding any testers and those that did not give informed consent, the following participants were excluded:

- those that did not answer the item about their constructivist beliefs;
- those that specified they were history teachers but not geography and/or RZG teachers. RZG is a subject that combines geography, history and political education (EDK, 2016) similar to social studies in other countries;
- those that were not teacher students, because there were too few to make comparisons;
- those that had not yet taught in school. This was evaluated based on an introductory question that asked whether they had not yet taught in school, had taught in school in the past (but were not currently teaching) or were currently teaching. Some participants answering that they had not yet taught in school did answer the question about strategies they used to address misconceptions. Nevertheless, they were excluded based on their answer to the initial question. Conversely, two participants wrote in the "other" field of the questions regarding methods and planning that they had "not yet taught" (both questions) or "not yet taught geography"/"never taught". This might refer to the same thing, as these questions asked about specific subjects while the general question at the beginning of the questionnaire asked about any teaching experience. It could also point to them checking the wrong answer in the initial question. To be cautious, both were excluded.

No other variables were used to check for data quality, except for the code fields, which were checked only for those participants that specified that it was not their first time participating in a #TCDTE survey. No participant had to be excluded because of that. For one these participants, because the code was found another time in the Q3 data set, the birthplace was used to check that it was not the same person.

The sample consists of 16 teacher students from Q1 and 67 from Q3. The sample is described in Table 2. 60.2% were currently teaching in school and 39.8% had taught in school but were not currently teaching (n=83).

6.4. Data preparation

In Q1, some questions were asked separately for geography and history, while in Q3 different subjects were combined. For these variables, if only one of the two was completed, that was the value used. For participants that e.g., studied both history and geography and thus filled out both, an average value was used. Therefore, the percentages of binary variables do not always add to 100%. The open text question was only filled out twice by one participant, answering the "same as in history" for the second.

For the open text answer on how participants dealt with misconceptions, the strategies were first coded deductively based on the evidence-based strategies from the literature review:

1. Reality (strategy 1 and 2);
2. Models/experiments/simulations (strategy 3);
3. Conceptual change texts (strategy 4);
4. Analogies (strategy 5);
5. Concept cartoons (strategy 6);
6. Conceptual change learning environments (strategy 7).

interest in geography didaktics Range: 1 ("doesn't interest me at all") to 4 ("interests me strongly")	M=2.75, Mdn=3, SD=0.75, range 1-4, n=83 % not or rather not interested: 33.7% % rather or strongly interested: 66.3%	**interest in history didaktics** Range: 1 ("doesn't interest me at all") to 4 ("interests me strongly"**)**	M=2.80, Mdn=3, SD=0.76, range 1-4, n=64 % not or rather not interested: 34.4% % rather or strongly interested: 65.6%
studying for grade band **Secondary 1 (usually grades 7-9)** **Secondary 1, already has primary certification** **Secondary 1 and primary (grades 1-6)** **Secondary 1 and 2** **Secondary 2 (usually grades 10-12)**	n=83 85.5% 1.2% 1.2% 2.4% 9.6%	**years of teaching experience** **less than 1 year** **1-5 years** **6-10 years** **11-15 years** **16-20 years**	n=79 45.6% 43.0% 6.3% 3.8% 1.3%
studying for **geography** **RZG and/or both geography + history**	n=83 21.7% 78.3%	**How many empirical studies relating to learning and teaching their subject are known (not just the name, but e.g., read the article or heard the results in a presentation)**	
range of year of birth	1960-1996 (n=81)	**from formal education (e.g., academic studies, formal professional development workshops)** (n=82)	0: 9.8% 1-5: 37.8% in between (average Q1): 2.4% 6-10: 19.5% 11-20: 19.5% 21-30: 8.5% 31-40: 1.2% 41-50: 1.2% 5 or less studies: 47.6% 6 or more studies: 50.0%
frequency of use of specialist literature (books, scientific journals, …) as an information regarding their subject **Range: 1 [("almost) not at all"] to 4 ("very often")**	M=3.46, Mdn=4, SD=0.63, range 2-4, n=81 (almost) not at all or rather rarely: 7.4% rather or very often: 92.6%		
either the participant and/or at least one of his/her parents born outside of Switzerland	33.3% (n=81)		
gender	male: 58.0% female: 42.0% other: 0%(n=81)	**from independent reading or e.g., heard on a conference** (n=82)	0: 34.1% 1-5: 42.7% in between (average Q1): 1.2% 6-10: 13.4% 11-20: 3.7% 21-30: 2.4% 31-40: 1.2% more than 50: 1.2% 5 or less studies: 76.8% 6 or more studies: 22.0%

Table 2. Sample description.

Just mentioning "text" would not be enough to be classified as strategy 4. Instead, it would either have to be called conceptual change or refutational text or be described along the lines of the parts listed in the literature review. Whether something is a conceptual change learning environment is hard to evaluate based on a short description, especially because the conceptual change environments described (strategy 7) are so different. Thus, conceptual change learning environments were coded as such if they were explicitly named or if they included all the different stages, i.e., (since the question already presupposes noticing misconceptions): discussing the misconceptions, presenting the scientific conception, applying the new concepts and reflection.

For a non-evidence-based strategy, "presenting the right answer" was included because, as the literature review showed, the efficacy of conceptual change learning environments (strategy 7) is often compared to a "traditional teaching" approach that includes schoolbook texts and/or a teacher presentation of the concept.

It was expected that not all teacher students' answers would fit into these categories. Thus, the remaining answers were coded inductively based on the data.

7. Results

7.1. Research question 1: Do participants see themselves as constructivist?

The results can be seen in Table 3. Based on Mann-Whitney-U tests, there were no significant differences by any of the variables tested.

M	Mdn	SD	range	very or rather constructivist	rather transmissionist
2.16	2	0.50	1-3	77.1%	20.5%

Table 3. Teacher students' beliefs (n=83).
"Evaluate yourself. If you click on the line a point appears. You can then move it. I think I am …" (Q1); "Evaluate yourself. This question refers to your respective subject(s), i.e., geography, history, politics, RZG, philosophy, ethics, religion, ERG. I think I am …" (Q3). Range: 1 (very constructivist) to 4 (very transmissionist).

7.2. Research question 2: Do participants in general use practices such as student-oriented methods, differentiated learning or planning their lesson based on the group of learners they are teaching that could be seen as indicators of a rather constructivist practice?

The results for students' statements about the type of methods they use in general are displayed in Table 4. Based on Mann-Whitney-U tests, there was a significant difference by use of specialist literature (p=0.016, n=81, Table 5).

M	Mdn	SD	range	rather teacher centered	very or rather student-oriented
2.72	3	0.59	2-4	34.9%	63.9%

Table 4. Teacher students' use of student-centered methods (n=83).
"Evaluate yourself. If you click on the line a point appears. You can then move it. I use …" (Q1), "Evaluate yourself. This question refers to your respective subject(s), i.e., geography, history, politics, RZG, philosophy, ethics, religion, ERG. I use …" (Q3). Range: 1 [predominantly teacher-centered teaching (*German: Frontalunterricht*, i.e., literally "front-of-class-teaching")] to 4 (predominantly student-oriented methods).

The results for the use of internal differentiation are shown in Table 6 in the context of the other methods included in the survey. Many of these methods can be used both in constructivist and transmissionist ways, such as working with worksheets.

	M	Mdn	SD	range	rather teacher centered	very or rather student-oriented
rare use of specialist literature (n=6)	2.17	2	0.41	2-3	83.3%	16.7%
frequent use of specialist literature (n=75)	2.75	3	0.59	2-4	32.0%	66.7%

Table 5. Teacher students' use of student-centered methods by group.

	M	Mdn	SD	range	no or rare use	rather very frequent use
whole class, questioning-developing teaching (n=83)	2.86	3	0.67	1-4	27.7%	72.3%
working with work-sheets(n=83)	3.33	3	0.63	1-4	6.0%	94.0%
extended teaching/ learning methods (e.g., mystery, role play, project, games, future work-shop) (n=83)	2.58	2.5	0.78	1-4	49.4%	48.2%
internal differentia-tion (differentiated learning task or learning environ-ment) (n=83)	2.70	3	0.76	1-4	34.9%	62.7%
teacher presentation (n=82)	2.55	3	0.64	1-4	43.4%	55.4%
working with the schoolbook(n=83)	2.69	3	0.93	1-4	38.6%	61.4%
group work(n=83)	3.24	3	0.57	2-4	7.2%	92.8%
working with learn-ing soft-ware, inter-net, social media, mobile apps, etc. (n=83)	2.24	2	0.77	1-4	65.1%	32.5%

Table 6. Teacher students' use of differentiation.
"How often do you use the following forms of teaching in geography or RZG classes? Please evaluate every suggestion. If you use a form of teaching especially frequently that is not named here, you can add it." (For the history part, it was "history or RZG") (Q1); "How often do you use the following forms of teaching in subject classes? Please evaluate every suggestion. If you use a form of teaching especially frequently that is not named here, you can add it. This question refers to your respective subject(s), i.e., geography, history, politics, RZG, philosophy, ethics, religion, ERG." (Q3). Range: 1 [(almost) not at all] to 4 (very frequently).

	M	Mdn	SD	range	no or rare use	rather very frequent use
low his. didaktics interest (n=22)	2.27	2	0.77	1-4	63.6%	36.4%
high his. didaktics interest (n=42)	2.83	3	0.75	1-4	26.2%	69.0%

Table 7. Teacher students' use of internal differentiation by group.

The "other" option was only chosen by nine participants. 55.6% specified no or rare use and 44.4% rather or very frequent use. Only three participants that chose rather or very frequent use specified something: one "pictures", one "independent learning (learning landscape)", and one "learning workshop".

Based on Mann-Whitney-U tests, there was a significant difference by interest in history didaktics (p=0.006, n=64, Table 7).

	M	Mdn	SD	range	no or rare	rather very frequent
ad hoc (n=80)	1.88	2	0.92	1-4	73.8%	26.3%
planned based on the topic (n=81)	3.37	3	0.56	2-4	3.7%	96.3%
planned based on the group of learners (n=82)	3.23	3	0.72	1-4	14.6%	85.4%
planned based on the form that is predominantly used by my colleagues (n=82)	1.93	2	0.79	1-4	75.6%	22.0%
planned based on my own subject-specific didaktical beliefs (n=81)	3.36	3	0.62	2-4	7.4%	92.6%

Table 8. Teacher students taking into account their learners during lesson planning.
"According to what do you decide which form of teaching do you use in geography or RZG classes? Please evaluate every suggestion" (for the history part, it was "history or RZG") (Q1); "According to what do you decide which form of teaching do you use in geography or RZG classes? Please evaluate every suggestion. This question refers to your respective subject(s), i.e., geography, history, politics, RZG, philosophy, ethics, religion, ERG." (Q3). Range: 1 [(almost) not at all] to 4 (very frequently).

Another possible indicator of a constructivist practice is taking one's learners into account when planning a lesson. The results are shown in Table 8 in context of other factors included in the study. The "other" option was used by six participants. 16.7% specified rather frequent use, the rest no or rare use. No one specified anything in the write-in option.

Based on Mann-Whitney-U tests, there was a significant difference by use of specialist literature (p=0.011, n=80, Table 9).

	M	Mdn	SD	range	no or rare	rather very frequent
low use of specialist lit. (n=6)	2.5	2.5	0.55	2-3	50.0%	50.0%
high use of specialist lit. (n=74)	3.26	3	0.70	1-4	12.2%	87.8%

Table 9. Teacher students taking into account their learners during planning by group.

7.3. Research question 3: Are participants aware of sources of students' conceptions?

The results are displayed in Table 10. Based on Mann-Whitney-U tests, there was a significant difference for media by migration background (p=0.007, n=81, Table 11).

Overall, 3.7% of participants rather or completely agree to only one source, 32.9% to two sources, 34.1% to three sources and 29.3% to all sources (M=2.89, Mdn=3, SD=0.88, range 1-4, n=82). Based on Mann-Whitney-U tests, there was a significant difference for number of sources agreed to (p=0.027, n=80, Table 11) by studies known independently.

	M	Mdn	SD	range	agree not/ rather not	agree rather/ completely
comes from lessons (n=83)	2.95	3	0.52	1-4	13.3%	86.7%
comes from education at home (n=83)	2.65	3	0.74	1-4	38.6%	60.2%
comes from the media (n=83)	2.99	3	0.64	1-4	13.3%	86.7%
comes from out-of-school activities (e.g., youth club, friends, volunteering) (n=82)	2.59	3	0.71	1-4	43.9%	56.1%
can be determined with certainty with regards to its origin (n=83)	2.03	2	0.77	1-4	75.9%	22.9%
cannot be determined with certainty with regards to its origin, because the beliefs of the students always also play an important role (n=83)	2.89	3	0.78	1-4	24.1%	75.9%

Table 10. Teacher students' ideas about sources of students' knowledge.
"How strongly do you agree to the following statements? The actual and applicable geographic knowledge that students have ... Please evaluate every suggestion" (for the history part, it was "historical knowledge") (Q1); "How strongly do you agree to the following statements? The actual and applicable subject knowledge that students have … Please evaluate every suggestion. This question refers to your respective subject, i.e., historical, geographical, philosophical, religious etc. knowledge" (Q3). Range: 1 (do not agree at all) to 4 (agree completely).

	M	Mdn	SD	range	agree not/ rather not	agree rather/ completely
comes from the media						
without migration background (n=54)	2.85	3	0.66	1-4	18.5%	81.5%
with migration background (n=27)	3.24	3	0.51	2-4	3.7%	96.3%
number of sources						
low number of studies known informally (n=62)	2.76	3	0.88	1-4	-	-
higher number of studies known informally (n=18)	3.28	3	0.75	2-4	-	-

Table 11. Teacher students' ideas about sources for students' knowledge by group.

7.4. Research question 4: Do participants notice students' misconceptions?

The results are displayed in Table 12. Testing whether they have noticed any misconceptions (independent of frequency) with the help of Cramer V showed no significant differences by any of the variables.

	%
no	29.3%
yes, rarely	43.9%
yes, in-between due to average Q1	1.2%
yes, frequently	25.6%
yes, any	70.7%

Table 12. Teacher students' noticing misconceptions (n=82).
"Have you recently noticed geographic misconceptions in your students?" (For the history part: historical misconceptions) (Q1); "Have you recently noticed misconceptions in your students in your subject? This question refers to your respective subject(s), i.e., geography, history, politics, RZG, philosophy, ethics, religion, ERG" (Q3).

7.5. Research question 5: If participants notice students' misconceptions, do they use evidence-based strategies to address them?

Of the 58 teacher students that noticed students' misconceptions, 43.1% did not specify anything they did to address them (no answer). One teacher student only wrote "My students have a hard time putting themselves in the shoes of other people/cultures/times (understanding the other)", i.e., no strategy was described, but just an issue. Thus, overall, 44.8% of those noticing misconceptions did not provide a strategy for dealing with them.

The strategies described by the other participants are shown in Table 13. Some answers were not easily categorized, as they for instance could be seen as either "(whole class) discussion" or "presenting the right answer". Notably, the evidence-based strategies "concept cartoon", "conceptual change learning environment", "analogies" and "conceptual change texts" were not described by a single participant.

Strategy	Examples of teacher students' answers
reality (3.4%)	"Misconceptions about water pollution. Noticed while working on it and addressed. Visit to a sewage treatment plant" "Residence status of foreigners was very unclear, arose from a guided tour through Basel with a migrant (offer MKB When have I finally arrived?) and could also be resolved there. Many parents of the students have different residence permits, so it was an unconscious topic among the students"
models/experiments/ simulation (1.7%)	"Location of the cantons → by means of a Switzerland model (approx.. 1.5m large) assigned the cantons, regular repetition and addition by waters, mountains, and important reference points"
reflection (3.4%)	"Ask back, let draw -> look at it again after unit" "Due to the assumption that there might be misconceptions, I asked the students' ideas at the beginning of the new topic (drawing a mental map). In this way, the students were able to continuously reflect on their (mis)conceptions while working on the topic and, if necessary, correct them"
application (1.7%)	"I then try to bring about a conceptual change by presenting the students with a problem that they cannot solve with their current concept. Then the new concept is developed, with which the posed problem can be solved"
address pre-conception (6.9%)	"e.g., what a volcano looks like –> at the beginning let draw a volcano and then throughout the lessons correct the conception" "Take up misconceptions and try to fix them"
unspecified conceptual change (3.4%)	"I try to confront the students with the scientific idea, to introduce them to it and to bring about a conceptual change" "Try to generate a new conception in the students with suitable materials and inputs, that stands students' examination"
contradiction (1.7%)	"Lead to the contradiction. Own concept was adapted"
presenting the right answer (12.1%)	"Briefly corrected" "I have explained the facts in the plenum according to the current state of knowledge"
(whole class) discussion (15.5%)	"Joint development of a correct representation" "Forward question. Opinion plenary"
being non-judgmental (1.7%)	"Try not do to judge, but offer other perspectives/options, present"
source critique (1.7%)	"I have noticed that it is imperative to read and question sources critically"
student research (1.7%)	"Assumption of the pupils: Asterix and Obelix --> a village existed in Gaul that Caesar did not take. I reacted objectively. I let the children research on given pages, whether this is true"

Table 13. Examples for the categories of strategies teacher students use to deal with students' misconceptions (n=58).
"Briefly describe how you responded to the misconceptions you noticed respectively whether and what you did, if applicable" (Q1 and Q3; the only difference was a synonym used for misconception).
Categorization based on open text answers, answers translated.

Using Cramer V to look at whether any strategy being described or not differed by the variables tested showed a significant difference by migration background (p=0.016, n=57). Of those that did not have a migration background (n=39), 56.4% did not describe a strategy, 43.6% did, while of those with migration background (n=18) 22.2% did not describe a strategy and 77.8% did.

Of those that said they are constructivist (n=44), 61.4% described some sort of strategy, while of those that were transmissionist (n=12), 33.3% described one. If one looks at the categories, those that are transmissionist and described a strategy were categorized as "(whole class) discussion", "being non-judgmental", "presenting the right answer" and "unspecified conceptual change" (one each). Among those that were constructivist the categories "(whole class) discussion" (7), "address pre-conception" (4), "application" (1), "contradiction" (1), "model" (1), "simply presenting the right answer" (6), "reality" (2), "reflection" (2), "source critique" (1), "student research" (1) and "unspecified conceptual change" (1) were found. Thus, even some self-described constructivist teacher students seem to think it is enough to simply tell the students the correct information to cause conceptual change.

8. Limitations

The sample size of the study was fairly small. Therefore, it had a low power for detecting significant group differences e.g., between constructivist vs. transmissionist participants. Thus, studies with larger sample sizes are needed.

This study did not analyze lesson videos or lesson planning documents. It relied on teacher students' reporting. Thus, there is a possibility for a "social desirability" bias in the answers.

For identifying strategies that teacher students use to deal with misconceptions, this study used an open text question because not much seems to be known about which strategies teachers in Switzerland actually use. However, in open answer questions, often only the first example that comes to mind is described. Thus, the answers might not represent the full range of strategies used by teacher students. In future research, one could first have a closed item where participants rate whether they have used a specific strategy already, and then an open answer field where they describe an example of how they have used this strategy to deal with students' misconceptions. An open answer item could then capture additional strategies they use that were not covered by the listed options.

Participants were only recruited through one institution in the German speaking area of Switzerland. Thus, the results might not apply to other areas in the German speaking Switzerland. Moreover, a previous study with geography teachers in Switzerland showed significant differences between the Swiss language regions (Schulman et al., 2021). Thus, the results of this study cannot be generalized. Future studies should compare teacher students' beliefs and strategies between the German, French and Italian speaking regions of Switzerland.

9. Conclusions

Based on teacher students' beliefs about themselves as constructivist or transmissionist and teacher students' beliefs about the sources of students' conceptions, there is a sizeable share of teacher students whose beliefs are not very supportive of conceptual change.

There is also a share of teacher students who do not report general practices that could be seen as more likely to be supportive of conceptual change, such as planning a lesson based on their learners.

More specifically, more than 29% of teacher students did not notice any misconceptions in their students. Some part of it might be an artefact of the question phrasing ("recently"). However, it could also be that, like for the participants of Barthmann et al.'s (2019) study, the importance of misconceptions and conceptual change strategies is simply not yet a part of their conceptions and practices. Another reason could be that, just like the participants in Scholten and Sprenger (2020)'s study, the teacher students had deficiencies in their content knowledge and because of that were unable to recognize students' misconceptions. As beginning teachers have a lot of different things to learn, it might also be that focusing on other issues during the lesson (such as classroom management or using

technology) led them to not pay attention to or being able to recall misconceptions. Some lesson set ups can also make it hard to notice students' misconceptions.

There were no significant differences between teacher students who saw themselves as constructivist and those that saw themselves as transmissionist for the chosen indicators of a generally rather constructivist practice, for knowledge of sources of students' conceptions, or for noticing misconceptions. This supports the research from Henderson and Dancy (2007) that having constructivist beliefs is not enough for using constructivist practices.

This study also shows that even among those teacher students that noticed misconceptions, a large share did not describe that they did anything about it. And even among those that described strategies to deal with misconceptions, evidence-based strategies were rare. Some evidence-based strategies were not even mentioned once.

Selected geographic misconceptions and conceptual change strategies are part of teacher education, but the results of this study seem to indicate that the current form is insufficient to lead to a lasting impact on the practice of many teacher students. However, the questionnaire did not include a question which courses the students had already taken and with which instructor. Future research could include such a question to see which and how many courses that include conceptual change strategies are needed to make a difference in teacher students' beliefs and use of conceptual change strategies. Moreover, pre-post-test design studies could be used to analyze teacher students' learning in greater detail and improve courses and learning materials.

One hypothesis that also should be explored is that conceptual change strategies are not modeled often enough outside of the geography/RZG education course sessions dealing specifically with that topic. For instance, introductory CK textbooks for geography such as Gebhardt et al. (2007) are not structured as conceptual change texts. Teacher CK misconceptions seem to be far less studied than student misconceptions, and few if any ready-to-use concept cartoons or other materials for conceptual change in geography at the teacher level seem to be easily available.

Moreover, depending on their mentoring teachers during their internships and the teachers they had when they were still students in school themselves, teacher students have seen the implementation of conceptual change strategies in real-life secondary school classrooms modeled frequently, rarely, or maybe even not at all. Future research could include that experience as an additional variable.

Teacher educators cannot rely on school textbooks to encourage teacher students to use evidence-based conceptual change strategies. Geography/RZG textbooks for school students such as Davanzo et al. (2018) include a limited number of models/experiments but do not seem to specifically address common misconceptions, in contrast to conceptual change texts. Textbooks for school as well as learning materials on platforms like Zebis also rarely, if at all, include other conceptual change strategies such as concept cartoons (Viehrig, 2020). Some geographic concept cartoons are available on the internet (e.g., overview on Viehrig, 2020), but they only cover few geographic topics and are often in English. They thus would have to be translated for learners in the German-speaking area of Switzerland. However, teacher students have very limited time to find and translate existing conceptual change materials or to create their own, since they have a lot of other things to deal with. The limited availability of ready-to-use materials such as conceptual change texts and concept cartoons might thus have contributed to these conceptual change strategies not having been used by the teacher students in this study.

Conceptual change strategies are discussed in specialist literature, both in research studies and in introductory textbooks. For instance, a model similar to the conceptual change learning environment used in the Reinfried (2006) study has been included into the introductory textbook to geography education for teacher students (Reinfried and Haubrich, 2015, p. 69, modified after Driver and Oldham 1986, p. 119). It includes the phases (1) finding out what students' conceptions are, (2) getting students to activate their conceptions by e.g., discussing them, (3) introducing the students to relevant new, scientific concepts, creating a cognitive conflict, (4) getting students to apply the newly learned concept and (5) helping students to reflect on their

learning and their change in conceptions. Variations of the model have also been included in other published lesson materials for teachers (e.g., Reinfried and Hug, 2008). A frequent use of specialist literature does seem to make a limited difference. Teacher students reporting a more frequent use of specialist literature say they use student-centered methods more frequently than the teacher students who say they do not use specialist literature that much. The more frequent specialist literature consumers also take their learners into account when planning lessons more frequently than those who read specialist literature less often. And teacher students that knew more studies from e.g., their own reading were aware of more sources for students' conceptions. Yet, for instance, no teacher student in our study described applying the full model outlined in Reinfried and Haubrich. Even using only a part of it (such as reflection or application) was rare.

The results of this study indicate that just consuming research might not be enough for applying it to their practice. This is in line with results of research in the U.K. by Maclellan (2016). Therefore, teacher educators and researchers need to find better ways to increase the impact of research on teachers and thus evidence-based practices (e.g., Schulman, 2022).

More research is needed on how to increase teacher students' CK and PCK to help them to recognize students' misconceptions and to use evidence-based conceptual change strategies such as concept cartoons, models/experiments, analogies, conceptual change learning environments or encountering reality. More research is also needed to strengthen the evidence for conceptual change strategies in geography. It is also important to create more ready-to-use conceptual change materials to facilitate the implementation of evidence-based conceptual change strategies in school and teacher education.

Acknowledgements

The #TCDTE project was supported by funds of the FHNW. Thanks to the participants. Thanks to the researchers who commented on the questionnaire during its development. Thanks to the two reviewers of this paper. Thanks to T.S.

References

1. Adamina M., "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", Dissertation, Westfälische Wilhelms-Universität, Münster, 2008.
2. Adamina M., Hertig P., Probst M., Reinfried S., and Stucki P., "Klimabildung in allen Zyklen der Volksschule und in der Sekundarstufe II. Grundlagen und Erarbeitung eines Bildungs-konzeptes. Schlussbericht Projektphase CCESO I 2016/2017 (vollständige Fassung)", 2018, www.globe-swiss.ch/files/Downloads/1568/Download/CCESO%20I%20Langbericht%202018.pdf.
3. Akbas Y. and Genctürk E., "The Effect of Conceptual Change Approach to Eliminate 9th Grade High School Students' Misconceptions about Air Pressure", *Educational Sciences: Theory & Practice*, 11, 4, 2011, pp. 2217-2222.
4. Atasoy Ş. and Ergin S., "The effect of concept cartoon-embedded worksheets on grade 9 students' conceptual understanding of Newton's Laws of Motion", *Research in Science & Technological Education*, 35, 1, 2016, pp. 58-73.
5. Avci O., "Schülervorstellungen zum Staat Israel. Welche Vorstellungen haben Schüler*-innen ausgewählter Abschlussklassen der Sek-undarstufe I zum Staat Israel?", Master thesis, School of Education FHNW, 2021.
6. Barthmann K., Conrad D. and Obermaier G., "Vorstellungen von Geographielehrkräften über Schülervorstellungen und den Umgang mit ihnen in der Unterrichtspraxis", *Zeitschrift für Geographiedidaktik*, 47, 3, 2019, pp. 78-97.
7. Beerenwinkel A., "Fostering conceptual change in chemistry classes using expository texts", Dissertation, Bergische University Wuppertal, Wuppertal, 2006.
8. Ben-Zvi Assaraf O. and Orion N., "A Study of Junior High Students' Perceptions of the Water Cycle", *Journal of Geoscience Education*, 53, 4, 2005, pp. 366-373.
9. Brockmüller S. and Siegmund A., "Erfassung und Entwicklung von Systemkompetenz –

Empirische Befunde zu Kompetenzstruk- tur und Förderbarkeit durch den Einsatz analoger und digitaler Modelle", *Zeitschrift für Geographiedidaktik*, 48, 1, 2020, pp. 31-49.
10. Brooks C., "Paper presented" at *IGU-CGE Conference*, Singapore, 2016.
11. Chambers S.K. and Andre T., "Are conceptual change approaches to learning science effective for everyone? Gender, prior subject matter interest, and learning about electricity", *Contemporary Educational Psychology*, 20, 1995, pp. 377-391.
12. Chambers S.K. and Andre, T., "Gender, Prior Knowledge, Interest, and Experience in Electricity and Conceptual Change Text Manipulations in Learning about Direct Current", *Journal of Research in Science Teaching*, 34, 2, 1997, pp. 107-123.
13. Chatziioannidis J., "Empirische Untersuchung zu Schülervorstellungen über die Geographie und Kultur Indiens Welches Vorwissen haben Lernende der 1. Oberstufe über die Geographie und Kultur Indiens?", Master thesis, School of Education FHNW, 2018.
14. Cochran K.F., "Pedagogical Content Knowledge: Teachers' Integration of Subject Matter, Pedagogy, Students, and Learning Environ-ments", 1997, https://www.narst.org/publications/research/pck.cfm.
15. Davanzo E., Aeby R., Baeriswyl E., Held S., Hugenberg R., Kardaetz S., Oberholzer F. and Stutz M., *Durchblick Geografie – Geschichte. Band 2. Sekundarstufe I*, Braunschweig, Westermann, 2018.
16. DGfG (Ed.), *Bildungsstandards im Fach Geographie für den Mittleren Schulabschluss mit Aufgabenbeispiele*, Selbstverlag Deutsche Gesellschaft für Geographie, 2012.
17. Edelsbrunner P.A, Schalk L., Schumacher R. and Stern E., "Variable control and conceptual change: A large-scale quantitative study in elementary school", *Learning and Individual Differences*, 66, 2018, pp. 38-53.
18. EDK, "Lehrplan 21. Räume, Zeiten, Gesellschaften (mit Geografie, Geschichte)", 2016, http://v-ef.lehrplan.ch/.
19. Egbers M. and Marohn A., "Konzeptwechseltexte – eine Textart zur Veränderung von Schülervorstellungen", *CHEMKON*, 20, 3, 2013, pp. 119-126.
20. Friedli J., "Armut in der Schweiz – eine Präkonzeptforschung. Was denken Jugendliche über Armut in der Schweiz?", Master thesis, School of Education FHNW, 2019.
21. Gebhardt H., Glaser R., Radtke U., and Reuber P. (Eds.), *Geographie. Physische Geographie und Humangeographie*, Spektrum, 2007.
22. Giamellaro M., *Pathfinder:* "Measuring experiential learning through network modeling", *Proceedings of the 2015 Symposium on Experiential Education Research, presented at the 43nd Annual International AEE Conference* (Portland, Oregon, USA, 22- 25 October 2015), 2015.
23. Grospietsch F. and Mayer J., "Angebot, Nutzung und Ertrag von Konzeptwechseltexten zu Neuromythen bei angehenden Biologielehrkräften", *Zeitschrift für Didaktik der Naturwissenschaften*, 2021, pp. 83-107.
24. Groß J., Hammann M., Schmiemann P. and Zabel J. (Eds.), *Biologiedidaktische Forschung: Erträge für die Praxis*, Springer Spektrum, 2019.
25. Hannah A.L. and Rhubart D.C., "Teacher perceptions of state standards and climate change pedagogy: opportunities and barriers for implementing consensus-informed instruction on climate change", *Climatic Change*, 158, 3-4, 2019, pp. 377-392.
26. Hashweh M.Z., "Effects of Science Teachers' Epistemological Beliefs in Teaching", *Journal of Research in Science Education*, 33, 1, 1996, pp. 47-63.
27. Heiniger Y., "Schülervorstellungen zu Tourismus in der Schweiz. Eine quantitative Studie als Beitrag zur geografiedidaktischen Rekonstruktion", Master thesis, School of Education FHNW, 2019.
28. Henderson C. and Dancy M., "Barriers to the use of research-based instructional strategies: The influence of both individual and situational characteristics", *Physical Review Special Topics – Physics Education Research*, 3, 2, 2007, pp. 1-14.
29. Jahn M., Viehrig K., Fiene C. and Siegmund A., "Mit Concept Maps systemisches Denken von Schüler/innen

bewerten", in Budke A. and Kuckuck M. (Eds.), *Geographiedidaktische Forschungs-methoden,* Lit-Verlag, 2015, pp. 340-367.
30. Kácha O., Vintr J. and Brick C., "Four Europes: Climate change beliefs and attitudes predict behavior and policy preferences using a latent class analysis on 23 countries", *Journal of Environmental Psychology*, 81, 2022.
31. Keogh B. and Naylor S., "Concept cartoons, teaching and learning in science: an evaluation", *International Journal of Science Education*, 21, 4, 1999, pp. 431-446.
32. Knauer J., "'Afrikabilder unter der Lupe' Theoretische Ansätze, empirische Ergebnisse und Darstellungen von Afrika südlich der Sahara in (geographie-) didaktischen Publikationen", Master thesis, Leibniz University Hannover, 2013.
33. Krüger D., "Die Conceptual-Change-Theorie", in Krüger D. and Vogt H. (Eds.), *Theorien in der biologiedidaktischen Forschung – Ein Handbuch für Lehramts-studenten und Doktoranden*, Berlin Heidelberg, Springer Verlag, 2007, pp. 81-92.
34. Kumi-Manu R.N., "Concept Cartoon as a Teaching Technique for Conceptual Change: A Ghanaian Junior High School Experience", *American Journal of Educational Research*, 9, 9, 2021, pp. 587-599.
35. Lane R., "Articulating the Pedagogical Content Knowledge of Accomplished Geography Teachers", *Geographical Education*, 22, 2009, pp. 40-50.
36. Lane R., "Experienced geography teachers' PCK of students' ideas and beliefs about learning and teaching", *International Research in Geographical and Environ-mental Education*, 24, 1, 2015, pp. 43-57.
37. Lane R. and Catling S., "Preservice Primary Teachers' Depth and Accuracy of Knowledge of Tropical Cyclones", *Journal of Geography*, 115, 5, 2016, pp. 198-211.
38. Linfield R. and Holbrey C., "Lava or vinegar? How science models can create misconcept-ions", *Primary Science*, 167, 2021, pp. 10-11.
39. Maclellan P., "Why don't teachers use education research in teaching?", 2016, https://eic.rsc.org/analysis/why-dont-teachers-use-education-research-in-teaching/2010170.article.
40. Martínez P., Bannan B. and Kitsantas A., "Bilingual Students' Ideas and Conceptual Change About Slow Geomorphological Changes Caused by Water", *Journal of Geoscience Education*, 60, 1, 2012, pp. 54-66.
41. McCuin J.L., Hayhoe K. and Hayhoe D., "Comparing the Effects of Traditional vs. Misconceptions-Based Instruction on Student Understanding of the Greenhouse Effect", *Journal of Geoscience Education*, 62, 2014, pp. 445-459.
42. Mills R., Tomas L. and Lewthwaite B., "Learning in Earth and space science: a review of conceptual change instructional approaches", *International Journal of Science Education*, 38, 5, 2016, pp. 767-790.
43. Murtaj-Zeneli S., "Schülervorstellungen zum Kosovo. Welche Vorstellungen haben Schweizer Sekundar-Schüler/Innen vom Kosovo?", Master thesis, School of Education FHNW, 2019.
44. Nas S.E. and Çalık M., "A cross-age comparison of science student teachers' conceptual understanding of soil erosion", *Problems of Education in the 21st Century* 76, 2018, pp. 601-619.
45. Naylor S. and Keogh B., "Concept Cartoons: What Have We Learnt?", *Journal of Turkish Science Education*, 10, 1, 2013, pp. 3-11.
46. Neuenschwander M.P., Mayland C., Niederbacher E. and Garrote A., "Modifying biased teacher expectations in mathematics and German: A teacher intervention study", *Learning and Individual Differences*, 87, 101995, 2021, pp. 1-9.
47. Obermaier G. and Schrüfer G., "Personal concepts on 'Hunger in Africa'", *International Research in Geographical and Environmental Education*, 18, 4, 2009, pp. 245-251.
48. Preston L., "Australian primary in-service teachers' conceptions of geography", *International Research in Geographical and Environmental Education*, 24, 2, 2015, pp. 167-180.

49. Reinfried S., "Conceptual Change in Physical Geography and Environmental Sciences through Mental Model Building: The Example of Groundwater", *International Research in Geographical and Environmental Education*, 15, 1, 2006, pp. 41-61.
50. Reinfried S., "Welche Unterrichtsstrategien verändern geographische Alltagsvorstellungen nachweislich? Eine empirische Studie zum Conceptual Change am Beispiel subjektiver Theorien über Grundwasser", *Geographie und ihre Didaktik*, 1, 2007, pp. 20-40.
51. Reinfried S., Aeschbacher U., Kienzler P. M. and Tempelmann S., "Mit einer didaktisch rekonstruierten Lernumgebung Lernerfolge erzielen – das Beispiel Wasserquellen und Gebirgshydrologie", *Zeitschrift für Didaktik der Natruwissenschaften*, 19, 2013, pp. 259-286.
52. Reinfried S. and Haubrich H. (Eds.), *Geographie unterrichten lernen. Die Didaktik der Geographie*, Cornelsen, 2015.
53. Reinfried S. and Hug F., "Von Eisklumpen, Eismeeren und Strömen aus Eis. Gletscherbewegungen sichtbar machen und Schülervorstellungen verändern", *Geographie heute*, 2008, pp. 40-47.
54. Reinfried S. and Künzle R., "Deutungsmuster des Klimawandels in Aussagen von Lehrpersonen und Konsequenzen für die Klima-Kommunikation im Unterricht", *Zeitschrift für Geographiedidaktik*, 47, 2, 2019, pp. 45-59.
55. Reinfried S., Rottermann B., Aeschbacher U. and Huber E., "Alltagsvorstellungen über den Treibhauseffekt und die globale Erwärmung verändern - eine Voraussetzung für Bildung für nachhaltige Entwicklung", *Schweizerische Zeitschrift für Bildungswissenschaften*, 32, 2, 2010, pp. 251-273.
56. Reinfried S. and Schuler S., "Die Ludwigsburg-Luzerner Bibliographie zur Alltagsvorstellungsforschung in den Geowissenschaften- ein Projekt zur Erfassungder internationalen Forschungsliteratur", *Geographie und Ihre Didaktik*, 3, 2009, pp. 120-135.
57. Reinfried S. and Tempelmann S., "Wie Vorwissen das Lernen beeinflusst – Eine Lernprozessstudie zur Wissenskonstruktion des Treibhauseffekt-Konzepts", *Zeitschrift für Geographiedidaktik*, 1, 2014, pp. 31-56.
58. Reitano P. and Harte W., "Geography preservice teachers' pedagogical content knowledge", *Pedagogies: An International Journal*, 11, 4, 2016, pp. 279-291.
59. Rempfler A., "Fachliche und systemische Alltagsvorstellungen von Schülerinnen und Schülern zum Thema Lawinen", in Reinfried S. (Ed.), *Schülervorstellungen und geographisches Lernen. Aktuelle Conceptual-Change-Forschung und Stand der theoretischen Diskussion*, Berlin, Logos, 2010, pp. 55-85.
60. Renkl A., "Vorwissen", 2000, www.wissenschaft-online.de/abo/lexikon/psycho/16532.
61. Scholten N. and Sprenger S., "Teachers' Noticing Skills during Geography Instruction: An Expert-Novice Comparison", *Journal of Geography*, 119, 6, 2020, pp. 206-214.
62. Schreier J., "Der Einfluss von klimawandelgegnerischen Desinformationsnachrichten und Verschwörungserzählungen. Eine empirische Grundlagenforschung bei Jugendlichen auf der Sekundarstufe 1", Master thesis, School of Education FHNW, 2021.
63. Schrüfer G., "Verständnis für fremde Kulturen. Entwicklung und Evaluierung eines Unterrichtskonzepts für die Oberstufe am Beispiel von Afrika", Dissertation, Universität Bayreuth, Bayreuth, 2003.
64. Schulman K., "Research publications' impact on geography teachers", in Artvinli E., Gryl I., Lee J. and Mitchell J.T. (Eds.), *Geography Teacher Education and Professionalization*, Springer, 2022, pp. 161-177.
65. Schulman K., Chatziioanndis J., Friedli J., Heiniger Y., Murtaj-Zeneli S., Suter C. and Studer L., "Geographische Konzepte von Lern-enden in der Schweiz: Ausgewählte Ergebnisse aktueller Masterarbeiten", *GeoAgenda*, 2020, 3, 2020, pp. 15-19.
66. Schulman K. and Demantowsky M., "Teacher students' conceptions of geography and their sources", *IRGEE*, submitted.
67. Schulman K., Fuchs S., Hämmerle M., Kisser T., Laštovička J., Notter N., Stych

P., Väljataga T. and Siegmund A., "Training teachers to use remote sensing: the YCHANGE project", *Review of International Geographical Education (RIGEO),* 11, 2, 2021.
68. Seroussi D.E., Rothschild N., Kurzbaum E., Yaffe Y. and Hemo T., "Teachers' Knowledge, Beliefs, and Attitudes about Climate Change", *International Education Studies*, 12, 8, 2019.
69. Serttaş S. and Yenilmez Türkoğlu A., "Diagnosing Students' Misconceptions of Astronomy Through Concept Cartoons", *Participatory Educational Research*, 7, 2, 2020, pp. 164-182.
70. Shabani-Gashi V., "Schülerinnen- und Schüler-vorstellungen zum Balkan. Welche Vor-stellungen haben die Schülerinnen und Schüler der Sekundarstufe 1 vom Balkan / von Albanien? Ist ihr Vorwissen zu Albanien negativ geprägt, wenn ja, warum?", Master thesis, School of Education FHNW, 2020.
71. Shulman L.S., "Those Who Understand: Knowledge Growth in Teaching", *Educational Researcher*, 15, 2, 1986, pp. 4-14.
72. Shulman L.S., "PCK. Its genesis and exodus", in Berry A., Friedrichsen P. and Loughran J. (Eds.), *Re-examining Pedagogical Content Knowledge in Science Education*, Routledge, 2015, pp. 3-13.
73. Taşlıdere E., "The Effect of Concept Cartoon Worksheets on Students' Conceptual Understandings of Geometrical Optics", *Education and Science*, 38, 167, 2013, pp. 144-161.
74. Thomm E., Gold B., Betsch T. and Bauer J., "When preservice teachers' prior beliefs contradict evidence from educational research", *British Journal of Educational Psychology*, 2021, pp. 1055-1072.
75. Viehrig K., "Exploring the effects of GIS use on students' achievement in geography", Dissertation, Heidelberg University of Education, Heidelberg, 2015.
76. Viehrig K., "Concept cartoons: teaching for conceptual change", 2020, www.katieschulman.com/2020/concept-cartoons/.
77. Viehrig K. and Rinschede G., "Psychologische Grundlagen", in Rinschede G. and Siegmund A. (Eds.), *Geographie-didaktik,* Paderborn, UTB, 2020, pp. 50-68.
78. Viehrig K., Siegenthaler D., Burri S., Reinfried S., Bednarz S., Blankman M., Bourke T., Brooks C., Hertig P., Kerski J., Kisser T., Solem M., Stoltman J., Behnke Y., Lane R., Lupatini M., Scholten N., Siegmund A. and Sprenger S., "Issues in improving geography and earth science teacher education: results of the #IPGESTE 2016 conference", *Journal of Geography in Higher Education*, 43, 3, 2019, pp. 299-322.
79. Viehrig K. and Siegmund A., "Water, wind & sun in kindergarten: development and empirical validation of an assessment instrument. Working Paper", 2018, www.researchgate.net/publication/329118098_Water_wind_sun_in_kindergarten_development_and_empirical_validation_of_an_assessment_instrument.
80. von Burg M., "Schüler_innenvorstellungen zu Ursachen von Armut. Ein Beitrag zur Präkonzeptforschung", Master thesis, School of Education FHNW, 2020.
81. Yates T.B. and Marek E.A., "Teachers teaching misconceptions: a study of factors contributing to high school biology students' acquisition of biological evolution-related misconceptions", *Evolution: Education and Outreach*, 7, 7, 2014, pp. 1-18.

