

Conceptions about Drinking Water of 10th Graders and Undergraduates

Christian Fremerey*, Anne K. Liefländer, Franz X. Bogner

Z-MNU (Centre of Mathematics & Science Education), Department of Biology Education, University of Bayreuth, Bayreuth, Germany

Email: *Christian.Fremerey@uni-bayreuth.de

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Abstract

Any everyday subject may trigger individual conceptions either scientifically correct or naively shaped (misconceptions, alternative conceptions). For any educator, knowledge about a pupil's individual perception may strongly support teaching success. Within this context, we see the use of drinking water as daily behavior loaded with conceptions. We monitored the perceptions of two different samples, of high achieving 10th graders and of undergraduates in Biology. All participants responded to three closed and three open questions requesting individual statements about drinking water. All open questions were categorized via qualitative content analysis mainly revealing the perception of drinking water as a clean product, precisely controlled and drinkable with no need for worry. In general, some alternative conceptions did not seem differ in both samples over the time of about five years: For instance, many see our drinking water as purified in sewage plants. However, differences between individuals exist: For example, whether water is consumed as tap or bottled water. Here, some name water hardness as the reason to not drink tap water, because they think it is harmful (although the very same participants prefer bottled mineral water). Other conceptions seem to change over time, such as the estimation about the remaining time until our drinking water might be used up, or familiarity with the term "virtual water". Summing up, we did find a positive attitude towards national drinking water policy, although major knowledge gaps need its mentioning. The relevance of these results and strategies for public and school teaching are discussed.

Keywords

Drinking Water, Misconceptions, Alternative Conceptions, Water Education, Water and Environment

*Corresponding author.

1. Introduction

In Germany, no consumer ever needs to worry about the quality of drinking water. Everywhere tap-water is drinkable unless it is explicitly marked as “not drinking water”. Drinking water is tested on a regular basis [1] to assure its high quality [2], the legal basis being the “Drinking Water Ordinance 2001” [3]. Before purification, raw water is mostly obtained from groundwater (73.8%), followed by surface water (14.5%, *i.e.* from lakes, rivers and large water reservoirs) and river bank filtrates or artificially enriched groundwater (11.7%) [2]. In general, only a few treatment steps are required within waterworks to produce clean drinking water, such as filtration through sand or micro filters and disinfection with ozone or UV light. After purification, the public supply network distributes water of high quality level. Used household water passes into a closed sewage system for purification in treatment plants where (household) pollutants are extracted.

Pereira and Pestana [4] reported that water as so common in our lives that everyone expects clean drinking water out of every tap. The European Commission Drinking Water Directive requires a drinking water quality report every three years for every member state [1]. The Report of the Federal Ministry of Health and the Federal Environmental Agency (BBGU) includes only supply systems with more than 1000 cubic meters daily usage and more than 5000 customers [1] [2]. In 2010, 85.8% of the German population consumed 4212.79 million cubic meters of drinking water (from central plants) from 2283 facilities. The analysis assured the required standards for over 99% of microbiological and chemical quality parameters. The only exemptions came from exceptional cases regarding agricultural “pesticides”. For example, in 1999 nitrate exceeded the limits in 1.1% of all probes, in 2004 in 0.13%, in 2007 in 0.08% [5] and in 2010 in practically 0% of all probations [2]. A similar pattern was reported for coliform bacteria. Consequently, an excellent water quality situation exists in Germany [2] [5].

Pupils and students “do not come into science instruction without any pre-instructional knowledge or beliefs about the phenomena and concepts to be taught” [6] (p. 671). Maybe some do really come into the classroom without significant prior knowledge of the specific subject [7], but this is regarded as an exception. In every case, personal experiences and opinions are added in classroom lessons. In all areas of our lives, individual experience regularly forms notions which often include a certain understanding about scientific concepts [8]. Such patterns are described as pseudo-knowledge, since those ideas may be scientifically correct, semi-correct or even incorrect. Especially in natural science, not everyone has a correct and well-founded scientific conception which is in harmony with the view of science view [9]. Sometimes research shows students’ conceptions as rather limited and naive [6], while Modell, Michael & Wenderoth [10] saw a student’s conception not always in line with generally accepted (scientific) views of a concept. Although those “misconceptions” are found in all areas of science and in all age-groups [11], we prefer the term *alternative conceptions* as do Calik and Ayas [12]: This is because pupils’ views are not always completely wrong and sometimes just spontaneous ideas. Nevertheless, the literature employs many different terms for this non-scientific conception: Novak [13] described it as *preconceptions*, Helm [14] as *misconceptions* and Lewis and Kattmann [15] as *everyday conceptions*. Pupils and students need to integrate newly acquired school knowledge and daily life experiences into their conceptions. Sometimes such alternative and own conceptions of pupils are anchored even stronger than scientific correct conceptions taught by a teacher. Because of this they “are firmly held and are often resistant to change” [9] (p. 298). Consequently, identifying alternative conceptions is of great importance, since teachers for example need to decide whether to build upon the ideas of pupils [16]: If they utilize it, they need to consider how to finally achieve a conceptual change. To follow this line of argumentation, detailed knowledge of conceptions is needed, even for outreach facilities which offer authenticity and novel learning environments. In other issues such as agriculture, students’ conceptions help to deepen knowledge [17]. Additionally, the presentation of information plays an important role in changing conceptions [18]. A conceptual change requires the acquisition of knowledge [19], whereby pupils can change their alternative conceptions to scientifically correct ones, leading Fröhlich, Goldschmidt and Bogner [17] to suggest specific interventions or programs for students. Sellmann and Bogner [18] suggest consciously confronting students with alternative conceptions as part of interventions. Franke and Bogner [20] concluded that the integration of alternative conceptions in teaching programs leads to positive effects on interest and well-being. Because of this, it is important for the design of teaching environments and material to research alternative conceptions [21]. Conceptions can be differently identified in different ways, e.g. by open questions [22] or concept maps [18].

A cross-national study on perceptions about drinking water quality, undertaken by Doria, Pidgeon and Hunter [23], classified high scores for the United Kingdom (UK) as well as for Portugal. Parag and Roberts [24] de-

scribed for most developed countries high water standards in general, and tap-water qualities specifically. However, despite good water qualities, the consumption of bottled water has dramatically increased [24]. In line with this, Saylor, Prokopy and Amberg [25] showed that significantly more women consume bottled water than men do in groups of American university students and undergraduate students. Over the last decade, the trust of the American public in tap-water has declined [25]. The most common arguments against the drinking of tap-water were: the perceived risks of tap-water and the perceived safety of bottled water as well as the taste and convenience of bottled water. But the only advantage of bottled water would be that the bottle is already full, contains gas and does not need filling. Nevertheless, this potential time-saving argument is easily countered by the extra shopping time required.

Other potential reasons for preferring bottled water may be modern lifestyle, a status symbol, more convenience or even health associations [24]. Doria [26] [27] showed country differences for preferring bottled water in the United States (US), Canada and France: In the US, health and risk were the most frequently stated reasons; Canadian and French consumers put more emphasis on the organoleptic value, e.g. water characteristics such as taste or odor. Interestingly, French studies before 2000 [28] demonstrated the appearance of a new category: hardness of water. Hardness is also affected by certain ingredients of the drinking water, in particular by calcium ions and magnesium ions [5].

Saylor, Prokopy and Amberg [25] saw bottled water in the US as the more trustworthy water, as being more strictly regulated and as a safer product. However, non-users of bottled water agreed on the benefits of tap-water: “a reduced environmental impact, with the relative convenience of obtaining water and its low costs compared to bottled water” [25] (p. 593). There is little evidence supporting the assumption that bottled water is safer than tap-water. In contrast, it is even partially less safe [25]. In the US, two different agencies carry responsibility for the control of drinking water, the Environmental Protection Agency (EPA) for the tap-water and the Food and Drug Administration (FDA) for the bottled water. In Germany tap-water is subject to more stringent controls than bottled water: Bottled water is tested less often than tap-water [24]. The argument that bottled water is safer or better for health, therefore, is not correct. According to Saylor, Prokopy and Amberg [25] the notion that bottled water is safer than tap-water stems from limited understanding of drinking water regulations.

Consequently, the objectives of our present study focus on existing conceptions about drinking water and potential differences between high school pupils and university students.

Specifically, we aim to find out a) how pupils and students evaluate German drinking water and b) whether they prefer to drink tap-water or bottled water from the supermarket. Furthermore, we want to obtain information about the conceptions they have on the curriculum-relevant topics c) “water cycle”; d) “drinking water purification” and e) “virtual water”.

2. Methods

Two samples were investigated in our study: 10th graders (N = 132; average age 16.5 years; *SD* = 0.63) and Biology students (N = 125; average age of 21.1 years; *SD* = 3.06). 35.6% of the pupils and 59.2% of our Biology students sample were females. Despite of the sex imbalance, no significant differences between male and female statements were found. Our student sample consisted of Biology undergraduates (freshman and sophomores) from the University of Bayreuth. The 10th graders came from eight different classes from five different locations in the state of Bavaria.

A paper-pencil-test with three closed and three open questions on the topic of drinking water was applied (Table 1). Predefined lines suggested the expected statement length. For each question, closed and open, short comments were expected.

Data Analysis

Responses to the closed questions were sum-scored. We scored them a 1: correct, 0: otherwise. The open questions were analyzed according to Mayring’s [29] qualitative content analysis to assign relevant categories: From the latter responses we extracted four to six categories representing the most frequent responses by specifying an anchor example for each category. Surplus answers were coded as “others”, missing answers were coded as “no answer”. Both samples yielded very similar categories. An intra- and inter-rater objectivity test confirmed the reliability of the categories by randomly selecting 10% of the participants’ answers from each subgroup, and determining Cohen’s kappa values [30] (please refer to Table 2). Using SPSS, version 21, we applied chi square

Table 1. Closed questions (CQ 1 - 3) with answer possibilities (italics), and open questions (OQ 4 - 6).

Number of question	Question
CQ 1	Is tap-water in Germany drinkable without worries? <i>a) drinkable without worries</i> <i>b) undrinkable</i> <i>c) not drinkable everywhere</i>
CQ 2	Is supermarket or tap-water better controlled? <i>a) tap-water is better controlled</i> <i>b) supermarket water is better controlled</i> <i>c) both are controlled on the same level</i>
CQ 3	Would you prefer a glass of tap-water or bottled water? <i>a) tap-water</i> <i>b) bottled water</i> <i>c) both</i>
OQ 4	Where is our drinking water purified?
OQ 5	Guess when drinking water will be used up on our planet!
OQ 6	What do you understand by the term “virtual water”?

Table 2. Cohen’s kappa scores for intra-and inter-rater reliability.

Questions	Cohen’s kappa	
	Intra-rater reliability	Inter-rater reliability
OQ 4	1.00	0.946
OQ 5	0.951	0.951
OQ 6	1.00	1.00

Note: Landis and Koch [48] interpreted scores between 0.81 - 1.00 as “almost perfect agreement”.

tests to analyze differences between pupils and Biology students in their frequency of chosen answers for the closed questions and for the frequency of the categories identified for the open questions.

3. Results

In all analyses, the school pupils’ and university student sample were treated separately:

CQ 1. Is tap-water drinkable without worries?

Tap-water is regarded as “drinkable without worries” by pupils (80%) and university students (72%). Particularly, the quality, hygienic factors and regular analytic controls were stated as reasons. Nevertheless, some regard it as “undrinkable” (pupils: 9%; students: 6%) or “not drinkable everywhere” (pupils: 9%; students: 20%). The adjacent comments often point to contaminated groundwater situations, e. g. caused by agricultural fertilizers, obsolete pipelines or missing background knowledge. Surprisingly, a very common concern dealt with too high lime content which was even seen as dangerous for humans. As a result, participants rated drinking water is undrinkable. Altogether, we found no significant differences between the answer frequency of pupils and university students, [chi-square] (3) = 7.30, $p = 0.063$.

CQ 2. Is supermarket or tap-water better controlled?

Tap-water was widely regarded as analytically better controlled than bottled water (52% pupils, 62% students), only a minority reporting supermarket water as better controlled (30% pupils and 18% students). Further explanatory arguments for tap-water included its general availability, its large quantity and even its lower likelihood of contamination due to a higher control density due to governmental regulations. Those who considered supermarket water as better controlled, argued that it is treated like all food articles. Some participants saw both kinds of water as equally well controlled (12% pupils, 15% students), expecting high quality for both. Again, differences in the conception between the two groups were not found: [chi-square] (3) = 5.617, $p = 0.132$.

CQ 3. Would you prefer a glass of tap-water or bottled water?

Bottled water was preferred by both 10th graders and undergraduates (Figure 1). Significant differences between pupils and undergraduates do exist ([chi-square] (3) = 12.372, $p = 0.006$), however, in the preference for drinking tap-water, where students outnumbered pupils ([chi-square] (1) = 8.435, $p = 0.004$, *contingency coefficient* = 0.178). The odds ratio showed students' consumption of tap-water to be more than twice as high as that of pupils. In contrast, pupils drink bottled water significantly more often ([chi-square] (1) = 7.769, $p = 0.005$, *contingency coefficient* = 0.171). The odds ratio showed pupils' consumption of bottled water to be more than twice that of students. Interestingly, both groups use similar arguments for justification: The advantages of tap-water were low costs, easy availability and good quality, for bottled water, a better taste and the availability of sparkling water. Pupils and students used the tap-water's lime content as an indication of quality (pupils: 21%, students: 32%; [chi-square] (1) = 3.840, $p = 0.050$, *contingency coefficient* = 0.121): High hardness of water was linked with low quality:

OQ 4. Where is our drinking water purified?

This open question produced three main categories of responses: “sewage treatment plant”, “water treatment plant” and “waterworks”. Only few participants were aware that German drinking water is purified at waterworks (pupils: 11%; students: 6%; [chi-square] (1) = 2.144, $p = 0.143$, *contingency coefficient* = 0.091). Most frequently participants checked “sewage treatment plant” (pupils: 35%; students: 31%) or “water treatment plant” (pupils: 25%; students: 25%) as the source for purification.

Especially in the category of “water treatment plant” the participants had some conceptions, but did not know the correct scientific term. Examples of responses for this category were: “in a plant were water is purified” or “in a water filtration plant”. We decided that “waterworks” and “water treatment plant” were two categories. One example for a response in the category “waterworks” was “drinking water is purified in waterworks”.

Some answers did not fit any category such as: “Drinking water is purified by a special industry”, “it is purified by a filter system” or “it is purified by the earth”. Here we decided on the category of “other”. Differences between pupils and students do not exist: [chi-square] (4) = 5.785, $p = 0.216$.

OQ 5. Guess when drinking water will be used up on our planet!

Five categories, as shown in Figure 2, covered all answers: Only few participants saw drinking water as an unlimited resource due to a perpetual cycle (Figure 2). Few others also stated that it can never be used up, by stating reasons like “it can be generated”, “we find new techniques for water extraction” or “never if you can convert salt water into drinking water”. Most participants rated drinking water as used up within the next one to a thousand years. Fewer participants judged it as lasting even longer, up to millions of years and provided answers like “the world will perish before/as long as the planet lives there will be water”. Some answers did not fit any category such as: “with global warming it goes faster” or “when the glaciers have melted”. Here we decided on the category of “other” (Figure 2). The results revealed differences in the conceptions of pupils and university students: [chi-square] (5) = 15.383, $p = 0.009$. These differences originated from the category “in several 1000 to millions of years”, [chi-square] (1) = 11.809, $p = 0.001$, *contingency coefficient* = 0.210. The odds ratio indicates that pupils' scores outnumbered the students' ones 5.73 times.

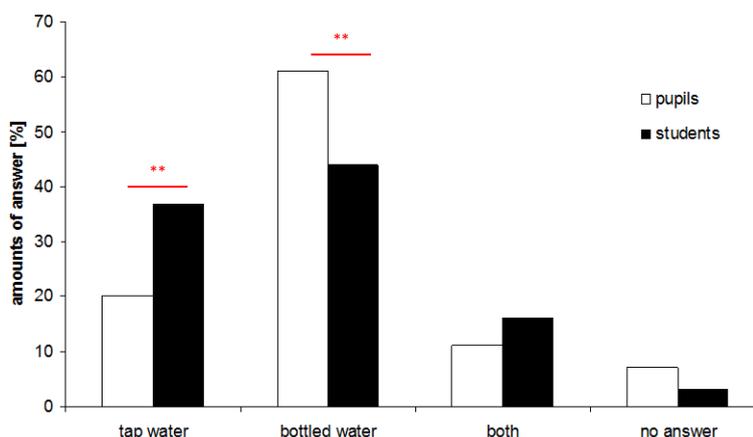


Figure 1. Categories for pupils' and students' statements to the open question “Would you prefer a glass of tap-water or bottled water?”.

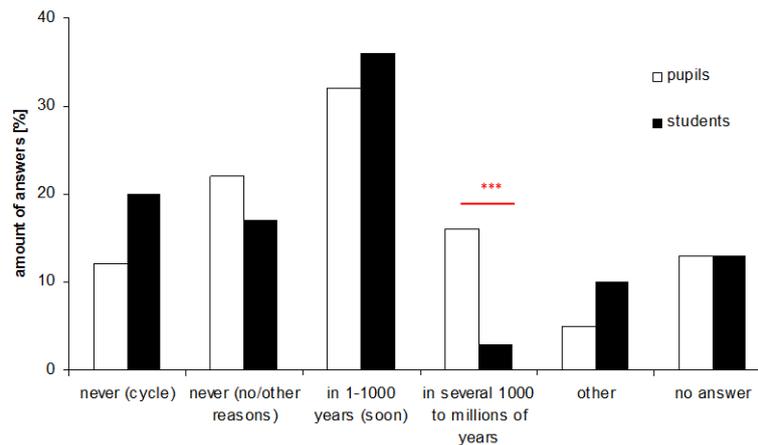


Figure 2. Categories for pupils' and students' statements to the open question: "Guess when drinking water will be used up on our planet!".

QQ 6. What is meant by "virtual water"?

Only few participants saw virtual water as used for the production of products ("water for production of products"; **Figure 3**). Some think it may be water displayed by a computer or in the internet ("water in computer/internet"). Nevertheless, most respondents had never heard of it or gave no answer. Examples of responses which cannot be categorized were: virtual water is "fake water that does not exist", "only theoretically available", "on the stock exchange traded water" or "water that is man-made" (all in the category "other"; **Figure 3**). The statements about virtual water led to the greatest differences between the two test groups, pupils and students, [chi-square] (3) = 37.263, $p < 0.001$.

In all four categories significant differences appeared: The category "water for production of products" revealed the strongest differences (pupils: 2%, students: 22%; [chi-square] (1) = 23.260, $p < 0.001$, *contingency coefficient* = 0.288). The category "water in computer/internet" has a significant difference (pupils: 15%, students: 3%; [chi-square] (1) = 10.832, $p = 0.001$, *contingency coefficient* = 0.201). The odds ratio revealed that the number of pupils thinking virtual water is "water in computer/internet" is 5.42 times higher than the number of students. A highly significant difference has the category "never heard" (pupils: 67%, students: 49%; [chi-square] (1) = 8.412, $p = 0.004$, *contingency coefficient* = 0.178).

4. Discussion

4.1. Scientifically Correct Conceptions

Within the first statement about drinking water judgments in Germany ("Is tap-water in Germany drinkable without worries?"), our results more or less correspond with our expectations and the literature. The majority of our participants (about 70%) demonstrated correct conceptions about drinking water qualities and its drinkability. In Germany drinking water is consumable without worries at all times [2]. The second statement supported the first: The majority of participants were convinced of the high quality of German drinking water. About 50% declared tap-water to be better controlled than supermarket water. As in the UK and Portugal [23], drinking water was classified as being of high quality, which again corresponds to the current status in Germany. In the comparison between the national drinking water regulation and the regulation of mineral water, drinking water is judged as analytically tested for significantly more pollutants than bottled water. Subsequently, most participants of our study have the right conception about the quality of drinking water/tap-water. They have strong confidence in the quality of national tap-water. This is for example different in the US: Saylor, Prokopy and Amberg [25] reported a substantial decrease in the faith of the American public in tap-water, whereas the confidence in bottled water seems to increase. In contrast to this result, in our sample a decline in positive judgments in drinking water does not appear; and more, there is strong confidence in German national drinking water/tap-water.

Considering the first and second statement, it is surprising that all participants know about the very good quality of tap-water in theory, but still both samples consume more bottled water-pupils significantly more than students. This is quite in line with the international situation: Parag and Roberts [24], for instance, described for

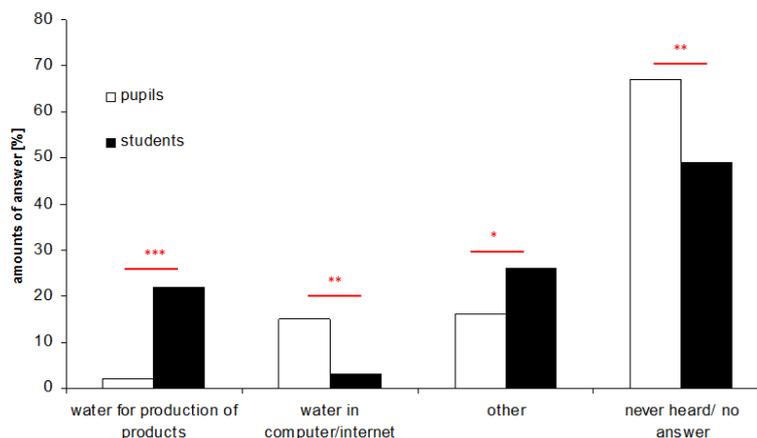


Figure 3. Categories for pupils' and students' statements to the open question "What is meant by 'virtual water'?"

the most developed countries (e.g., US, UK, French, etc.), where water qualities in general are good, an increasing bottled water consumption. In our study, particularly the younger participants consume significantly more bottled water than the older. Students report significant higher tap-water consumption than pupils, while the tap-water and bottled water consumers of students are nearly equal in number. This is in line with the results by Saylor, Prokopy and Amberg [25] from the US where more undergraduate students than graduate students preferred bottled water. That the older ones consume more tap-water than the younger indicates a certain confidence in tap-water, which contradicts the results of Saylor, Prokopy and Amberg [25]. Nevertheless, considering the fact that women drink more bottled water than men we came to the same conclusion as the authors mentioned above. Of course, the reasons for the various uses of drinking water are different. Most of the arguments raised in our sample (in favor of bottled water consumption with regard to safety and taste) are in line with other studies [24] [25]. Especially the taste and the sparkling feeling are the main reasons for preferring bottled water. As in Canada and France [26] [27], German participants seem to combine organoleptics, such as taste or odor with their preference of bottled water. In accordance with the literature [5] [28], we detected the hardness of water as another reason: Some participants refused to drink tap-water because of high lime contents. Apparently reinforced by the (commercial) media, hard water is considered bad water. Due to the fact that it is destroying and calcifying washing machines, it is also regarded as harmful to humans. This correlation surprises, since drinking hard water is not only harmless to our health, its calcium and magnesium contents provide important ingredients in our diet. In the present study, it was even more surprising that our older participants tended to ascribe to this concept: All of them must have known the chemical background from their high school science education, since without passing such chemistry examinations no admission to university is granted. Apparently, in this specific issue, students did not sufficiently link lesson contents with everyday knowledge.

A similar effect was described by Niebert and Gropengießer [31] in their study of concepts of climate change: Students mainly saw carbon dioxide "as something unnatural, chemical or toxic [...]" by statements like "normal air has no carbon dioxide" (p. 609). Some students even did not count carbon dioxide as a natural component of the atmosphere, just like the lime content concept in our study.

The very same ions (calcium, magnesium, etc.) are regarded as healthy in bottled water; most brands even use such contents as promotion arguments. Consequently, clarification of facts is needed about substances in drinking water and their relevance for human health. Another reason for the higher bottled water consumption of pupils may simply lie in copying parents' behavior. University students usually live alone and often declare economic reasons to drink tap-water: Actually, it is much cheaper than bottled water. In line with the literature [24] [26], substantial conservational reasons (for example, to avoid transport efforts) are other reasons to prefer tap-water. Further studies about the potential influences of age or education levels would provide helpful background information.

4.2. Alternative Conceptions

Alternative conceptions were examined in our fourth statement: Astonishingly, the majority of both samples

thought our drinking water was purified in sewage plants. In fact, there is nowhere in Germany where drinking water is supplied directly from sewage plants. These facilities purify waste water before releasing it back into nature. Probably the term “sewage plant” is just misused in place of “waterworks”. The latter simply refine already pure water before distributing it to the suppliers who by the way make drinking water/tap-water the best controlled food. Some participants even stated that drinking water was purified in a “water treatment plant”. In agreement with the literature [6], pupils and university students (again, both groups have very similar scores) have only universal ideas about the meaning of this term: for instance, they know that another purification step is needed between sewage plant and purified drinking water, but miscalled the scientifically correct term. Just a few participants in both samples (pupils: 11%; students: 6%) indicated that drinking water is purified in waterworks. There is not a significant difference, but twice as many pupils as students knew the correct answer. Saka, Cerrah, Akdeniz and Ayas [32] found similar results in their study on genetic concepts: Although higher graders would have a better understanding, in some cases lower graders achieved better results. Year by year pupils and university students accumulate new information and individual knowledge archives become more complex. While acquired knowledge may disappear again, alternative concepts may develop without complying with the scientifically correct ones [32].

The confusion of waterworks with sewage plants mentioned above seems a harmless misconception, but the water companies often face communication problems, as some people think they need to drink the water from the sewage plant. This case occurred in the US [33] when drinking water was planned to be recovered directly from waste water. Although the engineers had guaranteed safety standards and excluded any health threats, consumers completely rejected this kind of drinking water supply.

Another alternative conception is presented by our statement five concerning the subject “water cycle”. In school, everyone learns about cycles in nature, for instance, which elements are important and how water drops run through the water cycle. However, only a few can interpret this knowledge and apply it to different topics. The majority of our participants saw water as a resource which would soon be depleted. School does not providing pupils with in-depth knowledge [17] [19], which is certainly needed for conceptual change. Especially our older participants have two different parties: Some see water as an inexhaustible and endless source; others see it as limited in the near future. Had our participants absorbed the cycle view, no such disagreement would have arisen. Even if water is heavily polluted so that purifying is difficult, it still can neither be not used up nor diminish in quantity.

It is often said [34] that water is becoming scarce and that everyone has to consume less. The media in particular report on water shortages. This applies only to areas where, due to the geological conditions, water is a limited resource anyway. Similarly, when water is removed by agriculture or industry, groundwater levels often substantially drop. In a water-rich country like Germany, where only about 20% of the available water is used [35], this issue is irrelevant.

All participants had similar perceptions regarding statements four and five. No noteworthy significant differences could be observed. This indicates constancy over ages in individual concepts of “water purification” and “water cycle”. This is in line with other scientific views, for example on climate change [18] [31], because there exist alternative conceptions which are resistant to conceptual change regardless of information given by sources like school or the media.

The last statement concerning the term “virtual water” includes another interesting alternative conception because many participants had not yet heard the term. In our collected responses some participants combine personal experience with the concept and acquire alternative conceptions. We found significantly more pupils connect virtual water to computer games or internet in comparison to university students. This naïve conception may originate in a mere linguistic aspect and individual experience, since the participants associate the term “virtual water” with computers. The word “virtual” is used in everyday language differently, as in science, and thus leads to a different understanding. This problem also affects other scientific fields such as genetics or climate change [31] [36]. In this context the linguistic similarity of the German term *Treibgas* (meaning propellant gas) and *Treibhausgas* (meaning greenhouse gas) is well-known: A more detailed expression such as “climate-active gas” might already help to clarify the confusion here [31]. Probably participants with such alternative conceptions have never heard the term before, but they developed an interpretation. This conflict is similar to other cases in the literature [6] [8] [9]. Indeed, this interpretation often does not represent the correct scientific conception, but corresponds with daily life experiences of the pupils. In this case the university students followed more frequently the scientifically correct conception. Education and instruction or age and experience [37]

seem to play a role, although the curriculum neither of 11th and 12th graders nor the undergraduate studies dealt with the subject “virtual water”. Apparently, other sources have contributed to the issue such as daily experience, TV or media. In agreement with the literature we come to the conclusion: Learners do not only acquire information from school but also from the media, such as newspapers, books or the internet [36] [38]. Posner, Strike, Hewson and Gertzog [39] have even described learning as a rational activity that is a kind of inquiry.

4.3. Strategies for Public and School Teaching

Our study shows young people expressing mainly positive attitudes towards drinking water, but also indicating knowledge gaps and alternative conceptions. For educators, it is of great interest to know students’ alternative conceptions as we have described above. Furthermore, educators need to know about potential teaching strategies available to change these conceptions. In the literature, the presentation of information and the acquisition of knowledge are identified as important factors for conceptual change [18] [19]. However, pupils sometimes cannot build upon profound scientific knowledge [17]: Their alternative conceptions may also be resistant to change as they are often grounded in everyday experiences [9].

Instruction can focus on confronting students with their alternative conceptions. This cognitive conflict strategy was found to positively influence conceptual change [18] [40] [41]. However, cognitive conflicts need a meaningful and relevant connection for students’ everyday life [42] [43]. The confrontation with individual alternative concepts can produce more positive emotions and may increase motivation for learning [20] [44]. Repetition of scientifically correct conceptions can also last longer, when students resolve the conflict with their everyday perceptions [45]. Next to the cognitive conflict strategy, where learners actively have to reorganize their knowledge, conceptual change can also “build on learners’ existing ideas and extend them through, for example, metaphor or analogy, to a new domain”. [46] (p. 2). This strategy counts on suitable program design by the educator to support scientific concepts.

Alternative conceptions can function as starter or mental instruments for learning processes [31] from which a scientific understanding can grow [15]. According to Chi [47] (p. 61), there are three different ways to achieve conceptual change in a learning process: Revision of a belief, transformation of a mental model or categorical shift. The latter is most complex, because alternative and scientifically correct conceptions fall into different lateral or ontological categories; refuting the alternative concept is therefore difficult. A possible communication strategy to change conceptions is described by Niebert and Gropengießer [31] (pp. 618-619): “1) Give students access to their conceptions; 2) discuss the consequences of the domain-specific use of the schema; 3) help students to reconstruct their conceptions to the scientific concept”. Suitable teaching approaches seem to be hands-on activities (like open inquiry based science education, experiments or “learning at workstations”) or relevant real-life topics [48]. Especially in combination with individual discussions, for example, during collaborative science activities, and reflection on the learning process, these teaching approaches can foster a change towards scientifically correct conceptions—for example on drinking water.

5. Conclusion

In conclusion, alternative conceptions in the subject of drinking water are real, in part, they differ substantially from the scientifically correct ones. This discrepancy may make communication difficult and may lead to an understanding gap. As our study shows, a strong confidence in tap water contrasts a high consumption of bottled water. This discrepancy may reason in the often existing alternative conception that tap water comes from a treatment plant. Other problems are technical terms, associated with other experiences, such as virtual water. This altogether can lead to unbridgeable misunderstandings in everyday life communication. In general, it needs mentioning that young people often build upon superficial and scientifically incorrect knowledge leading to incorrect conclusions about water. Educational efforts with in-depth analyses need to overcome these gaps.

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