Educ. Sci. **2014**, *4*, 213–228; doi:10.3390/educsci4040213

OPEN ACCESS

education sciences

ISSN 2227-7102

www.mdpi.com/journal/education

Article

Learning about Drinking Water: How Important are the Three Dimensions of Knowledge that Can Change Individual Behavior?

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External Editor: James Albright

Received: 1 August 2014; in revised form: 6 October 2014 / Accepted: 13 October 2014 / Published: 6 November 2014

Abstract: Clean drinking water, our most important resource, needs comprehensive protection. Due to its ubiquitous availability, the awareness of the importance of clean drinking water has partially vanished. Therefore, sensitizing within this context and improving individual ecological behavior has become an important issue in science curricula. We developed a student-centered guided-learning module based on nine workstations, with the themes: occurrence rates, purification methods, cleaning guidelines, distribution patterns, use and consumption, pollution, problems, types of drinking water and virtual water. One hundred and seventy four ninth to eleventh graders participated in our outreach intervention. All tasks presented via workstations were completed before participants inspected a nearby reed sewage treatment plant and completed hands-on experiments. For empirical analyses, we collected the newly acquired knowledge in three dimensions: system-knowledge, action-related knowledge and effectiveness knowledge, which together are assumed to provide a sufficient basis for conservation behavior. System knowledge directly affects action-related and effectiveness knowledge and these two types of knowledge, in turn, affect directly the ecological behavior. At all three test schedules, the three dimensions of knowledge correlated with each other, especially in both follow-up tests. The relevance of these results for schools is discussed.

Keywords: drinking water; system knowledge; action-related knowledge; effectiveness knowledge; learning at workstations; hands-on; student-centered; outreach module

1. Introduction

The overall importance of water is evident: without water there would be no life on earth. We rely on it as we drink it, use it to clean and to produce products. That is why water needs to be protected by everyone. Therefore, governmental authorities require continuous review of drinking water: For Germany, the European Community directive for drinking water and the German "Drinking Water Ordinance 2001" regulates the details [1,2]. Regular tests are the basis for the generally good to excellent water quality in most developed countries (e.g., [1,3–5]). Especially in European countries, drinking water is ubiquitous and has a high quality standard and an ubiquitous availability. Nevertheless, the general public does not sufficiently appreciate the value of these benefits [6], because it becomes something for granted. For instance, in the Bavarian curriculum drinking water is only an optional issue for fifth graders within the subject of "nature and technology" [7]. It is up to the teachers whether the theme is taught or not. For many teachers the issue do not seem important enough just because of its self-evidence. An appropriate teaching method is needed to help teachers to address this complex topic and to raise the level of conservation behavior.

Cognitive knowledge about environmental issues commonly is regarded as essential to value its context and importance as well as to reach individual behavior dimensions [8]. In environmental psychology research, knowledge is even commonly regarded as a determinant of conservation behavior [9]. The idea is that deeper knowledge about the causes of environmental problems may result in a more appropriate behavior. According to Kaiser and Fuhrer [10], mediation of information may teach what people can contribute to protect the environment: "before someone can act, he or she must know how things should be and what can be done" [10] (p. 600). Within this view, individuals follow a cost-benefit ratio of action. A large body of literature analyses this complex issue (e.g., [9]). Consequently, Kaiser, Roczen and Bogner [11] as well as Roczen, Kaiser, Bogner and Wilson [12] postulated that required knowledge as threefold, consisting of (1) system knowledge; (2) action-related knowledge; (3) effectiveness knowledge. The first (system knowledge), contains factual knowledge about how an environmental system works or how natural processes run. Environmental system knowledge describes basic scientific knowledge, and can be defined as "knowing what" [9]. The second (action-related knowledge) consists of knowledge about possible actions: Frick *et al.* [9] defined it as "knowing how". The third (effectiveness knowledge) includes comparing different options or actions to decide which is more effective. Frick *et al.* [9] supported empirically the theoretical distinction between the three dimensions of knowledge. Subsequently, this view was adapted to an environmental competence model [11,12] suitable for educational interventions: Hereby, three types of knowledge are arranged within a triangle form, which has been extended by the conservation behavior towards a diamond shape. Further extensions of the model followed in very recent studies (e.g., [12]). The model describes the relationships between the types of knowledge as well as their influence on conservation performance. It supports the notion that knowledge can affect general ecological behavior. However, system knowledge does not act directly on conservation behavior, but it affects the other two types of knowledge [9,12]. It is regarded as a basis for action-related and effectiveness knowledge: System knowledge helps in the search for origins of environmental problems [13] and appropriate actions as well as information on the effects of these actions [14]. Action-related knowledge and effectiveness knowledge affect conservation behavior directly [12]. Frick *et al.* [9] described action-related knowledge as slightly more widespread than system knowledge, although action-related knowledge was more accessible than the other two types of knowledge. In the study of Frick *et al.* [9], where the theoretical distinction between the three dimensions of knowledge was the first time empirically supported, effectiveness knowledge was apparently the least common one of the three types of knowledge. Consequently, environmental programs intending to influence conservation behavior need to include all three types of knowledge. Based on the model of Roczen *et al.* [12], a higher knowledge level in all dimensions is a basis for general ecological behavior. Of course, we regard many other factors as influencing pro-environmental or conservation behavior, as it is, for instance, described in the model of Roczen *et al.* [12]. However, we will restrict our study on the knowledge level, as in school it is most likely to achieve changes there. Thus, cognitive achievement should be a basic requirement of environmental programs.

In learner-centered methods teachers act as mentors and do not affect learning processes directly [15] while pupils work and learn at workstations with self-instructional (hands-on) material within small groups as in Randler, Baumgärtner, Eisele and Kienzle [16]. Learning is an active process and learning at workstations, as a learner-centered method, has many advantages. The cooperative learning environment addresses especially the social competences [17]. Pupils work autonomously and discuss their results with each other in groups. Herrington and Oliver [18] as well as Sturm and Bogner [19] observed that pupils show more motivation and interest for the topic in a learner-centered learning atmosphere in comparison to a teacher-centered one. This is quite in line with Randler and Bogner [20], Randler *et al.* [16] as well as Meissner and Bogner [21]: At learner-centered workstations, well-being may score higher than in teacher-centered lessons. Regarding the role of cognitive achievement, results differ: Studies such as Randler and Bogner [22], Schaal and Bogner [23] or Sturm and Bogner [19] described a complete lack of significant differences between student- and teacher-centered methods. Other studies indicated for learner-centered methods higher retention scores [24] or an increase in short- and long-term cognitive outcome [20]. Heyne and Bogner [25] reached similar results between student-centered and teacher-centered learning units. However, a third group with guided-learning at workstations produces even better results. Based on the literature, learning at workstations seems to be a very useful method for educational programs.

We tend to give short-term educational programs a greater emphasis than long-term, because short-term programs are more convenient, due to tight school schedules. Teacher usually takes their classes no longer than one day out of school. Short-term or one-day interventions positively affect knowledge for over four weeks [26], while long-term interventions promote individual attitudes or behavior in addition [26,27]. The efficacy of a short-term program especially on the cognitive level is in line with many other studies, e.g., [28,29]. All of them supported the position that pupils could acquire high knowledge levels through a short-term educational program lasting for up to six weeks. Kossack and Bogner [30] reported high motivation scores for a short-term intervention, too. Therefore, short-term programs need more attention as they may add additional value compared to classroom lessons by simply providing authentic environments (e.g., [17,30–32]). Especially first-hand experience may help pupils to better understand what they have learned [33]. Other advantages of out of school programs are their effect on environmental perception [34] and their yielding of a higher increase of knowledge levels, that remain constant even after several weeks [35,36].

Lieflaender *et al.* [27] first implied all three types of environmental knowledge simultaneously in a learning program: Within a syllabus issue of water ecosystems, the potential increase in all dimensions of environmental knowledge was tested. Within the frame of a four-day educational program with student-centered methods (e.g., learning at workstations), system knowledge produced a higher increase than action-related knowledge and effectiveness knowledge. Lieflaender *et al.* [27] additionally reported a high knowledge-level and strong knowledge convergence as well as a strong inter-correlation between knowledge increase of all three types. In our approach, we focused on the subject of drinking water, with the intent of influencing a basis to influence conservation behavior towards protecting water. In all areas of life, personal experience affects our notions, which may contradict the scientifically correct conception. Pereira and Pestana [6]; Taiwo, Ray, Motswiri and Masene [37]; Dickerson, Callahan, van Sickle and Hay [38]; Doria, Pidgeon and Hunter [5] or Fremerey and Bogner [39] pointed to alternative conceptions [40] or pre-instructional knowledge [41]. Based on these results, it is important to develop teaching materials especially for higher grades, since the subject of drinking water includes complex issues such as purification, water usages or contamination problems. These issues exceed existing learning materials such as the primary school learning program of Lieflaender, Bogner, Kibbe and Kaiser [27].

The objectives of our study were two-fold: First, to examine all three knowledge dimensions within our drinking water module and to check the reliability and validity of our *ad-hoc* questionnaire and to monitor short- and long-term achievement levels within all types of knowledge. Second, to analyse relationships within all knowledge scores of the three testing cycles: pre-existing, short-term achievement (directly after the learning program) and persistent knowledge (six weeks after the learning program); especially regarding the relationships between the three types of knowledge increase due to intervention.

2. Methods

Based on the literature (e.g., [18,26,35]), we developed a short-term outreach educational program following a guided-learning unit at workstations. Our educational intervention took place in the forest field centre ("Jugendwaldheim") in the Bavarian Forest National Park. Nine learning stations (we use learning stations synonymous with learning at workstations) were displayed indoors, each located on separate tables arranged in a large circle. We had implemented the three types of knowledge in each workstation. Any station could be chosen by pupils to enter the learning circle, for all nine stations a 15 min processing time was scheduled. We formed groups of three or four participants who worked together during the complete module. The learning circle was student-centered and the groups rotated every 15 min by finally passing through all the stations. The modules dealt with are: Amount of available water resources, purification methods, cleaning guidelines, distribution, use and consumption, drinking water types, pollution, problems and sustainability and virtual water. All stations dealt differently with the contents: some included smaller hands-on experiments, information texts, brochures, diagrams, tables, information films or documentaries/interviews. Participants could acquire the content of a station either in written texts or in short films or a hands-on experiment. We have chosen a variety of learning methods to offer variation to our participants in acquiring the taught content. After the learning circle, participants stopped at a nearby reed sewage treatment plant and saw in real life the cleaning power of natural soil, especially by examining an odor sample. In an experimental setup with different soil layers (sand, gravel, rough stones and humus), the importance of intact soil layers for the purification was given a grounding. In this manner, within this setup authentic experiences contributed to the concept of sustainability, for instance, when soil contaminants reaching the groundwater were highlighted. Altogether, during a 1-h period after the learning cycle, participants learned about purification of raw and waste water and drinking water analysis in an experimental setup, where they participated in several experiments. Only one teacher guided the intervention and the material and place of the program were always the same.

A sample of 174 ninth to eleventh graders (average age of 15.4 year; *S*D = 1.20) participated in the intervention. 47% were female. Participants were randomly selected and came from seven different schools in the state of Bavaria (Germany). Despite the age imbalance, no significant differences in knowledge between lower and higher graders were found. In our study, a test-design with pre-, post- and retention test was applied: The pre-test, two weeks before the intervention, the post-test, directly after, and the retention test about six weeks later. The time slot for retention test was cited in Lieflaender *et al.* [27]. We had just over 200 participants, thus the retention rate of the three tests was quite satisfactory. A paper-and-pencil-test with 27 items on the topic of water was applied. The questions and answers were randomly mixed at the three testing schedules, to avoid potential remembering effects of positions for correct answers. The questions covered all three environmental knowledge dimensions, system knowledge (SYS), action-related knowledge (ACT) and effectiveness knowledge (EFF). Each type of knowledge was measured with nine items. An expert team in education consisting of twelve individuals independently classified the questions into the three knowledge dimensions. Some questions were also in line with the literature of Roczen *et al.* [12] or Lieflaender *et al.* [27] and were partially taken for the survey. Each multiple-choice item consisted of four potential answers, of which only one was correct. The participants were never aware of the testing schedules, just in order to avoid a memorization of consciously questions.

Responses to the knowledge questions were sum-scored, a correct answer scored with 1, an incorrect with 0. For SPSS analyses, we used version IBM SPSS Statistic 22 and for Rasch analyses the program ConQuest 3.

A control group of 33 pupils of similar age (average age of 15.7 year; SD = 0.62) and educational level (two different classes of tenth graders) completed the same multiple-choice test as the treatment group, but did not take part in the intervention. Participants originated in two different regional schools.

3. Results

At first, we used the dichotomous Rasch model in order to analyse the item reliabilities and difficulty distribution [42]. In the Wright-map (see Figure 1), on the left side, the ability of participants is displayed and on the right side the whole items. The participants on the left side are marked with X. Each X represents 0.6 cases. The person ability is between plus three and minus three. A person with positive person ability has a higher probability to answer the items correctly than a person with negative person ability. Persons at zero have the ability to answer fifty percent of all questions correctly. The person-separation-reliability is 0.734. The test is suitable for separating our sample. On the right side all items are distributed according to their difficulty. The item with the most positive value (item 3, see Figure 1) is the most difficult one. The item with the highest negative value (item 14, Figure 1) is the easiest one. We have listed our twenty-seven questions and it can be seen that the three knowledge dimensions were distributed well according to their difficulty. The separation reliability of the items is 0.967. Every type had some difficult and some simple questions. The test appeared as too easy since more questions were in the negative range. This is because in the Rasch model the post-test should be used for the calculation of the difficulties [42]. The pre-test and the retention test would provide a falsified result. Before the intervention, the probability is high that most of the questions cannot be answered. The calculation would determine a too difficult test. It is similar with the retention test, because after a few weeks participants usually cannot remember everything. The reliability for the *ad-hoc* knowledge-questionnaire was, using Cronbach's alpha (0.74), a level above the threshold of 0.6, which Lienert [43] (p. 246) proposed to properly differentiate between individuals.

We also analysed the difficulty index (number of right answers/number of items) of the questions. They are all located between the threshold 0.2 and 0.8 [44]. For post-test mean scores of the questions of the three knowledge dimensions were: SYS: 0.60, SD = 0.20; ACT: 0.56, SD = 0.24; EFF: 0.54, SD = 0.17, meaning e.g., that 60% of the pupils answered the system knowledge questions correctly.

The distribution of our data via Kolmogorov-Smirnov calculation, corrected with Lilliefors [45], indicated a high significance ($p < 0.001$) for the complete knowledge-data and the Q-Q diagram confirmed the lack of normality. We repeated this procedure subsequently with the data set of all three knowledge dimensions separately: system knowledge (SYS), action-related knowledge (ACT) and effectiveness knowledge (EFF). None of the three dimensions followed a normal distribution, hence we applied non-parametric tests for calculations: The differences between the three test schedules and between the three knowledge dimensions were analysed by using the Wilcoxon-test, because of the distribution [45]. We used KN0 for the pre-knowledge, KN1 for the short-term acquired knowledge and KN2 for the retained knowledge.

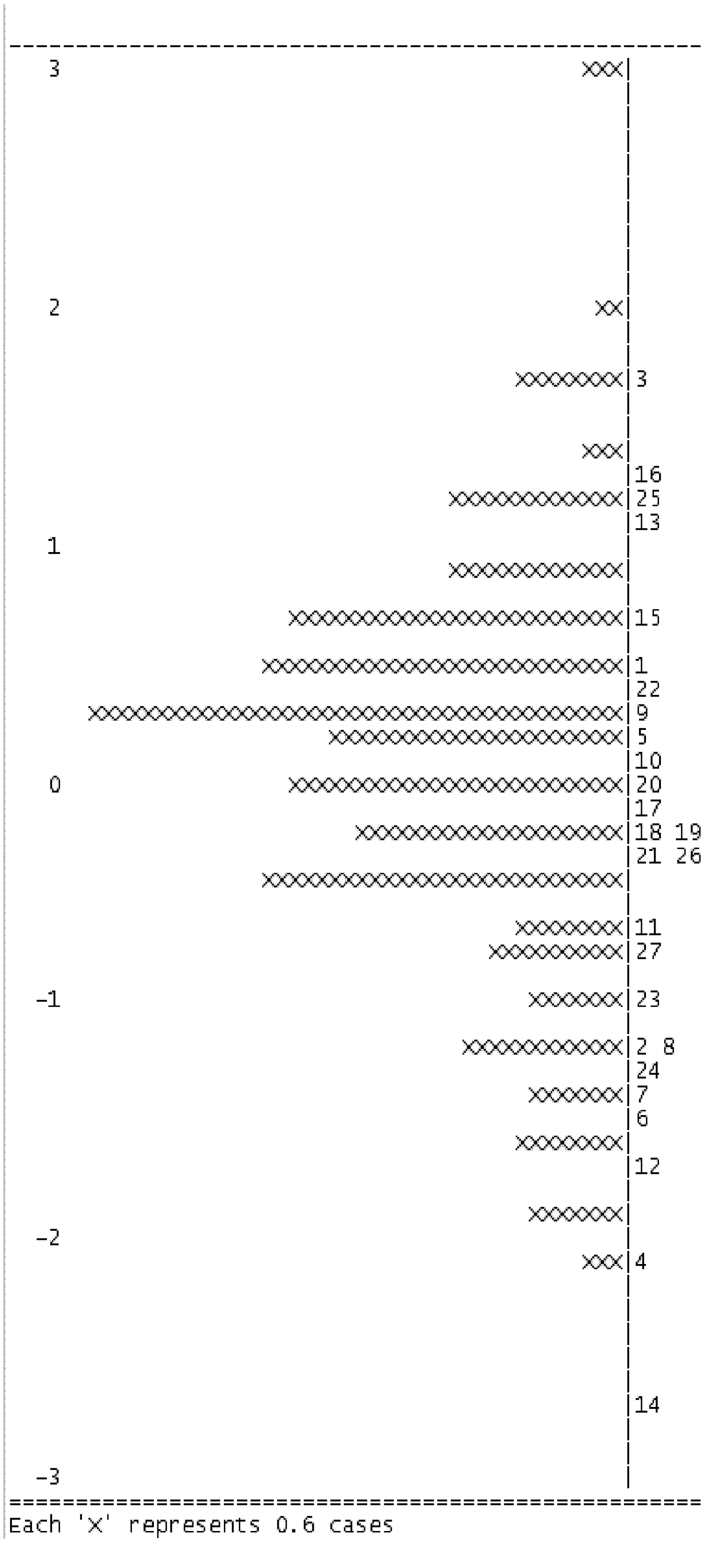
A control group showed no significant difference ($p = 0.62$; T = 1.933; mean score of KN0 = 10.73, SD = 2.45 and KN1 = 9.94, SD = 3.19) with the intervention groups. The comparison with an external control group was necessary, because this analysis showed that the observed effects were actually attributable to the intervention.

The intervention group showed significant differences for all knowledge-test schedules: KN0-KN1: $p < 0.001$; Z = −10.05; KN0-KN2: $p < 0.001$; Z = −6.54; KN1-KN2: $p < 0.001$; Z = −7.71. The mean scores scored for KN0 = 9.87 (SD = 2.91); KN1 = 15.28 (SD = 4.43) and KN2 = 12.13 (SD = 3.78).

Subsequently we analyzed the differences between the three dimensions of environmental knowledge. For all three knowledge dimensions significant differences were found between the three test times: (1) SYS: KN0-KN1: $p < 0.001$; Z = −8.74; KN0-KN2: $p < 0.001$; Z = −2.99; KN1-KN2: $p < 0.001$; Z = −7.06; (2) ACT: KN0-KN1: $p < 0.001$; Z = −6.49; KN0-KN2: $p = 0.014$; Z = −2.47; KN1-KN2: $p < 0.001$; Z = −4.74; (3) EFF: KN0-KN1: $p < 0.001$; Z = −10.19; KN0-KN2: $p < 0.001$; Z = −8.34; KN1-KN2: $p < 0.001$; Z = −6.01.

The mean sum scores were: (1) SYS: KN0 = 3.51 (SD = 1.44); KN1 = 5.36 (SD = 1.74); KN2 = 4.01 (SD = 1.80); (2) ACT: KN0 = 3.98 (SD = 1.46); KN1 = 5.13 (SD = 1.79); KN2 = 4.32 (SD = 1.59); (3) EFF: KN0 = 2.38 (SD = 1.30); KN1 = 4.78 (SD = 1.97); KN2 = 3.80 (SD = 1.57). The potential maximum of mean sum score would be nine of every type of knowledge, since we had nine questions for each one.

Figure 1. Rasch Wright-map of all 27 knowledge-items.



3. Which of the following substances has the highest allowed limit according to Drinking Water Ordinance? (SYS)

16. For environmental protection is the least useful, that you... (ACT)

25. Which of these dangers impacted groundwater at least in Germany? (EFF)

13. Costs of table water compared to tap water are on average more than... (EFF)

15. The different ground layers clean the seepage water very well. How should we build the individual layers in an experiment that these natural events come close? (ACT)

1. The purchase of which supermarket-water is most damaging to the environment? (ACT)

22. What could be the rising nitrate levels in groundwater are mainly reduced? (ACT)

9. Why water companies can not react with smaller pipes to the lower water consumption? (ACT)

5. The purification method of adsorption uses the ability that certain substances other... (SYS)

10. How must the filtering techniques for an optimal cleaning be arranged? (SYS)

20. By forgoing what product you can save the most virtual water? (EFF)

17. How much water can be saved with an aerator (a tap attachment)? (EFF)

18. How much water can be saved when you shower instead of bathe? (EFF)

19. How many liters run off per day solely on the toilet? (EFF)

21. Pressing the toilet flush once needs as much water as… (EFF)

26. What percentage of the world's water resources can be used as drinking water? (SYS)

11. In addition to the oceans, there is another large water reservoir in the water cycle! Which one? (SYS)

27. How many parts of the earth are covered by water? (SYS)

23. In addition to the oceans, there is another large water reservoir in the water cycle! Which one? (SYS)

2. Which sentence is true of the natural water cycle? (SYS)

8. With your own mobile phone you can save water by... (ACT)

24. What percentage of all water on Earth is salt water? (SYS)

7. If you drink bottled water instead of tap water, this water is... (EFF)

6. Purification plants and water works can almost completely remove contaminants, but you should… (ACT)

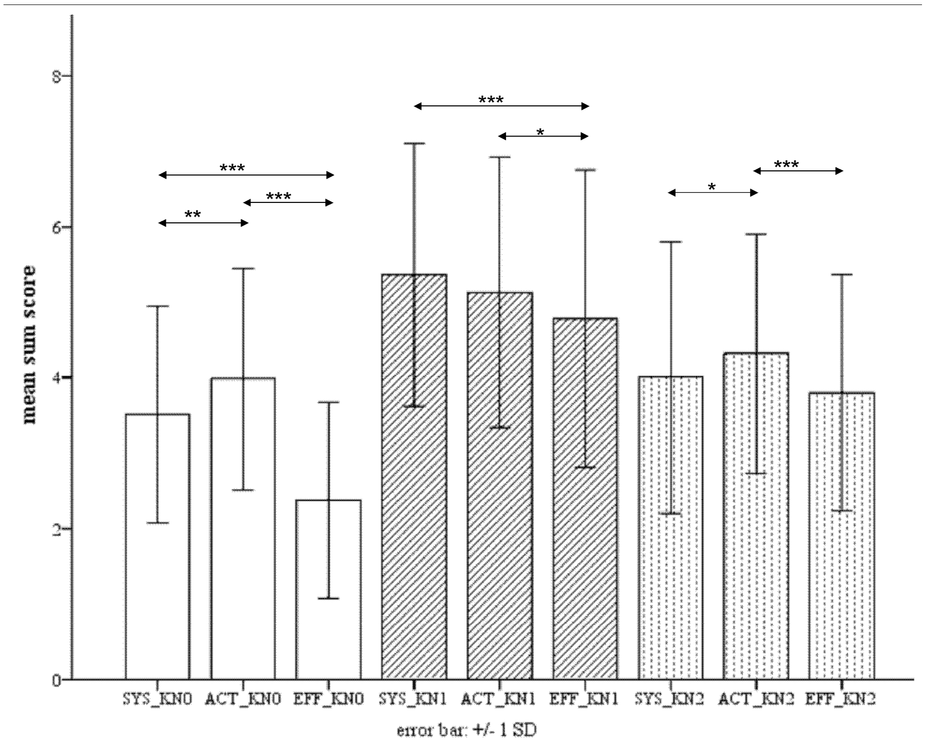
12. Which rule could be followed in the use of cleaning agents to contaminate water as little as possible? (ACT)

4. Out of which water type Germany wins almost no drinking water? (ACT)

14. What should you do in your own garden to protect groundwater? (ACT)

Figure 2 details both the differences between the three test times and the differences between the three knowledge dimensions.

Figure 2. The mean sum score of the three knowledge dimensions of the three tests.



All knowledge dimensions scored differently in the three test schedules. We tested the mean sum scores of the three knowledge types, comparing tests pair-wise using the non-parametric Wilcoxon-test in SPSS. Figure 2 details high to highly significant differences: For the pre-test: SYS-ACT ($p = 0.001$; $Z = -3.34$); SYS-EFF ($p < 0.001$; $Z = -7.37$); ACT-EFF ($p < 0.001$; $Z = -9.17$). For the post-test: SYS-ACT ($p = 0.054$; $Z = -1.93$); SYS-EFF ($p < 0.001$; $Z = -3.78$); ACT-EFF ($p = 0.013$; $Z = -2.47$). For the retention-test: SYS-ACT ($p = 0.021$; $Z = -2.32$); SYS-EFF ($p = 0.185$; $Z = -1.33$); ACT-EFF ($p < 0.001$; $Z = -3.64$).

To further visualize the short- and long-term acquired knowledge, differences scores for the test times were calculated (Figure 3).

The differences in Figure 3 are tested with the non-parametric Wilcoxon-test. The short- and long-term acquired knowledge of the three knowledge dimensions were significantly different: ΔKN1-KN0: ACT/SYS: $p < 0.001$, $Z = 3.78$; EFF/SYS: $p = 0.005$, $Z = 2.83$; EFF/ACT: $p < 0.001$, $Z = 6.26$; ΔKN2-KN0: ACT/SYS: n. s., EFF/SYS: $p < 0.001$, $Z = 4.91$; EFF/ACT: $p < 0.001$, $Z = 5.76$.

Finally, we correlated the corresponding pre-, post- and retention-tests of all three knowledge dimensions. For our multiple testing we corrected alpha-value following Bonferroni (which corrects for the number of mutually interdependent comparisons): Consequently, an alpha-value of 0.008/0.002/0.0002 was applied for all correlations in our study. In Figure 4, you can see significant Spearman-Rho correlations between the knowledge dimensions (SYS0-ACT0: $p = 0.014$; SYS0-EFF0: $p = 0.008$; ACT0-EFF0: $p = 0.001$; SYS1-ACT1: $p < 0.0002$; SYS1-EFF1: $p < 0.0002$; ACT1-EFF1: $p < 0.0002$; SYS2-ACT2: $p < 0.0002$; SYS2-EFF2: $p < 0.0002$; ACT2-EFF2: $p < 0.0002$).

Figure 3. Acquired knowledge differences of the three-dimensional environmental knowledge.

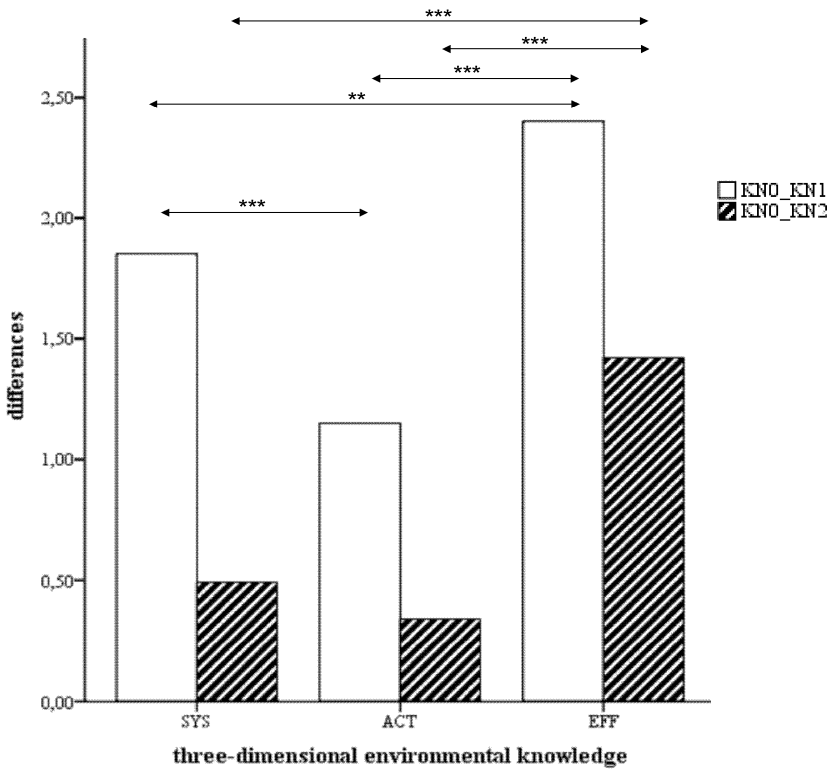
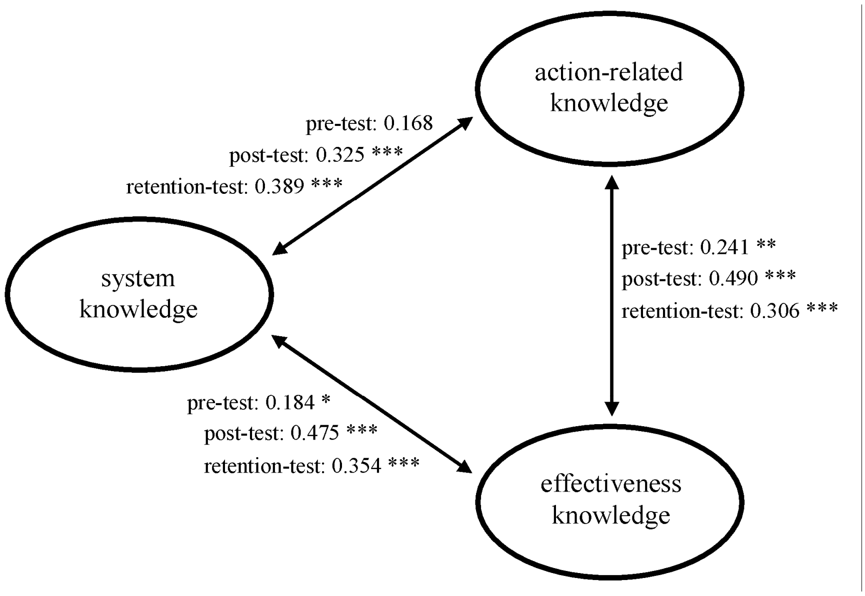


Figure 4. Three dimensional knowledge model with correlations.



Note: *p*-value ***** = 0.008; ****** < 0.002; ******* < 0.0002.

Finally, we analyzed the relationship of the three dimensions of knowledge between the post- and the retention test (Spearman-Rho correlation due to the non-normally distributed data; see Table 1).

The normal alpha-value used a threshold of <0.05. After applying a Bonferroni-correction (see above), an alpha-value of 0.016 was employed.

Table 1. Correlations between short- (T-1) and long-term (T-2) knowledge.

T-1	Analysis	SYS2	ACT2	EFF2
SYS1	Spearman-Rho correlation	0.241	0.166	0.300
	significance	0.001	0.014	<0.001
ACT1	Spearman-Rho correlation	/	0.240	0.182
	significance		0.001	0.008
EFF1	Spearman-Rho correlation	0.283	0.271	0.428
	significance	<0.001	<0.001	<0.001

The short-term system knowledge correlated significant with all long-term type of knowledge. The same applied to effectiveness knowledge in the post-test, it has the highest correlations with the three knowledge dimensions in the retention-test. Short-term action-related knowledge only correlated with itself long-term knowledge and long-term effectiveness knowledge.

4. Discussion any conclusion part?

Our project-specific three types of knowledge questionnaire can be seen as reliable, as the Rasch model and Cronbach's alpha analysis show. Simultaneously, the Rasch model and the calculation of the difficulty indices revealed separation of easy and difficult items in the post-test of all kinds of knowledge (see Figure 1). This is another positive feature of our developed scale, showing the average of difficulty indices between the three types of knowledge as quite similar. System knowledge items are only marginally easier than the action-related knowledge items, and both types are easier than the effectiveness knowledge items.

4.1. Success of the Intervention

In the pre-test, participants gave the most correct answers in action-related knowledge followed by system knowledge. Apparently, pupils had a more profound lack of knowledge in the dimension of effectiveness knowledge compared to the other dimensions (see Figure 2: SYS_KN0; ACT_KN0; EFF_KN0). These findings are in line with the findings of Frick *et al.* [9], where effectiveness knowledge was shown to be the least prevalent, with only 52.9% correct answers, compared to 54.4% at system knowledge and 55.4% at action-related knowledge. Lieflaender *et al.* [27] reported a lower average mean for effectiveness knowledge compared to the other scales. After six weeks we identified the same distribution of the kinds of knowledge as before (see Figure 2: SYS_KN2; ACT_KN2; EFF_KN2). In particular, the percentage of correct answers was nearly equal in all three types of knowledge: that is, the difference between the dimensions became smaller. In the retention-test effectiveness knowledge was only statistically different to action-related knowledge. The level of all knowledge dimensions has been aligned by our learning program. After the intervention the differences between the three types of knowledge were not as big as before the intervention. From pre- to retention-test, the level of the three knowledge dimensions increased to a comparable one.

In the post-test, another distribution of the three dimensions of knowledge emerged (see Figure 2: SYS_KN1; ACT_KN1; EFF_KN1): Immediately after intervention, the most correct answers were found in system knowledge scale and significantly less in the effectiveness knowledge scale. However, this may simply be due to the already mentioned marginal differences in the difficulty indices of the three items scales. Answering the system knowledge scale was apparently easier than the effectiveness knowledge scale, which as a fact may explain why SYS_KN1 in Figure 2 has the most correct answers compared to ACT_KN1 and EFF_KN1.

In line with Kaiser *et al.* [11], we defined success of the educational program as an increase in knowledge level. Our intervention produced a significant increase over all three knowledge dimensions. This is in line with other studies (e.g., [27,35]) and indicated the effectiveness of our student-centered, short-term and out-of-classroom environmental education program.

Pupils benefit from the educational program, although retention knowledge is limited: Six weeks after the intervention, we detected a general knowledge decrease over all knowledge dimensions. However, in comparison to the pre-test level, a significant increase in knowledge for all three types was still measurable after this time. This increase and subsequent decrease of knowledge after a certain time, according to an intervention with work stations, corresponded to the literature (e.g., [16,22,23]). The decrease was smallest for effectiveness knowledge and highest for system knowledge (see Figure 3). This contradicts Lieflaender *et al.* [27] who reported decrease effects as smallest for system knowledge and highest for effectiveness knowledge, explaining this thus: "a decrease in system knowledge or action-related knowledge would also lead to a decrease in effectiveness knowledge" [27] (p. 13). However, the study of Lieflaender *et al.* [27] had produced the strongest increase in system knowledge, which would mean in their explanation that effectiveness knowledge would have to rise as well: Lieflaender *et al.* [27] saw their program outline as a possible reason for the limited increase and persistence of effectiveness knowledge. It could also be explained by the youth (mean age 10.44 years), of the sample Lieflaender *et al.* [27] examined. Perhaps younger participants do not understand the practical implications and therefore have problems with this complex knowledge dimension.

4.2. Importance of Effectiveness Knowledge

Frick *et al.* [9] consider effectiveness knowledge as highly important, even though they obtained low scores. Kaiser *et al.* [11] showed the three knowledge dimensions as mutually dependent. System knowledge includes knowledge about facts and is likewise a basis for action-related knowledge and effectiveness knowledge. Action-related knowledge includes knowledge about alternative actions and is therefore a precondition for effectiveness knowledge. To achieve knowledge increase in effectiveness knowledge the other two dimensions of knowledge are needed. Lieflaender *et al.* [27] reported the highest increase in system knowledge and the lowest in effectiveness knowledge. These results supported the opinion that the difficulty of the three knowledge dimensions decreases from effectiveness, to action-related, to system knowledge. In our study, the increase of knowledge for EFF is highest (Figure 3). It seems more difficult to gain knowledge in system knowledge or action-related knowledge than in effectiveness knowledge. However, participants start with a high level in system and action-related knowledge, meaning that high pre-knowledge is given in comparison to effectiveness knowledge (see Figure 2). Hence effectiveness knowledge can reach even higher levels. This result is not in line with Lieflaender *et al.* [27], where participants have nearly similar pre-knowledge levels in all types of knowledge. Higher grades seem to acquire the three dimensions of knowledge differently. System and action-related knowledge seem more available at the pupils whereas effectiveness knowledge seems least prevalent. Such pre-knowledge-levels of the three knowledge types are in line with the literature [9]. If an educational program, like our intervention, manages to impart effectiveness knowledge, the participants deal so deeply with the issue, that they retain this specific type of knowledge in a better way. We apparently reached this deeper dealing through repeated involvement by specifically backing different learning methods, e.g., textual work, videos or experiments. Effectiveness knowledge seems the most interesting section for pupils, because the acquired level of this knowledge dimension is the highest and the later-on decrease the smallest (see Figure 3). It seems that they would rather learn something which is more effective for the environment (and/or also for them). This would be another explanation why effectiveness knowledge gain is highest. Participants may link all three dimensions of knowledge with each other within the effectiveness knowledge and thereby retain it longer. Apparently, the program and perhaps age-group selection are crucial variables. Nevertheless, more research is needed to finally answering the question, which variables are the crucial ones for the different results in the effectiveness knowledge between Lieflaender *et al.* [27] and ours.

4.3. Relationship between Three Knowledge Dimensions

Kaiser *et al.* [11] assumed that with successful instruction not only knowledge level can be increased, but also the relationship between the three different dimensions can be strengthened. A more recent study of Lieflaender *et al.* [27] confirmed this: Correlations increased from pre- to post-test, and some correlations increased in the retention-test as well. In this case, our results are in line with the literature. The increase from pre- to post-test is expected following intervention, but we found higher correlations in the retention test as well. The relationship between system knowledge and action-related knowledge increased significantly over all test times from 0.168 to 0.389 (see Figure 4). The relationship between system knowledge and effectiveness knowledge as well as action-related knowledge and effectiveness knowledge increased due to our intervention, although a postponed retention-test demonstrated a decrease of this knowledge convergence again (see Figure 4). The correlations observed in the pre-test demonstrate the initial situation of the relationships between the three types of knowledge. In the "notional picture of three circles" of Lieflaender *et al.* [27] (p. 13), the status-quo is the starting point of the three knowledge dimensions before participants have learned something about the topic. The three knowledge circles overlap only slightly. An interpretation could be that knowledge is just loosely linked before intervention. Within the learning program, all knowledge dimensions have been learned and thus the knowledge types are linked to each other. The knowledge circles (of our thinking model) became bigger and it came to a stronger overlap of these, which illustrated an integration of the knowledge dimensions into one another. The relationships with effectiveness knowledge in the retention-test decrease again (Figure 4), and continue to rise marginally between system knowledge and action-related knowledge. One possible explanation could be the different complexity of the three kinds of knowledge: For system knowledge, no other kind of knowledge is required and for action-related only system knowledge is the basis. These two knowledge dimensions are self-contained. However, in the relationship of system knowledge or action-related knowledge with effectiveness knowledge (in Figure 4), the other type of knowledge may play a certain role. Kaiser *et al.* [11] labeled this context as "Competence model for environmental education":

(1) System knowledge influences action-related and effectiveness knowledge; (2) Action-related knowledge influences effectiveness knowledge; (3) Effectiveness knowledge includes system and action-related knowledge. The dependencies of the three knowledge dimensions of Kaiser *et al.* [11] are shown in Table 1, where correlations between short-term and long-term knowledge level are calculated: All three types of knowledge are linked to each other. Each knowledge dimension that was acquired directly after the intervention, affects itself with regards to the retention knowledge level. All other correlations reflect the results of Kaiser *et al.* [11] and Roczen *et al.* [12]: System knowledge correlates with action-related and effectiveness knowledge and action-related knowledge with effectiveness knowledge. Effectiveness knowledge correlates with system and action-related knowledge. These results underline the importance of all knowledge dimensions and their mutual influence. In line with Frick *et al.* [9], we tend to give effectiveness knowledge more importance: This type of knowledge has the highest effect on all knowledge dimensions and a directly influence on conservation or general ecological behavior [11,12]. For these reasons we think this type of knowledge is very important for an environmental education program. It has the highest potential to influence the other variables in the environmental competence model [12]. Another positive aspect of effectiveness knowledge may be seen in the low decrease rate six weeks after participation.

The increase of knowledge level, unfortunately, is not reflected in the increase relationships in Figure 4: Effectiveness knowledge shows the strongest growth within the knowledge levels, but relationships with the other two knowledge dimensions fall again in the retention-test. We have no explanation for this result.

4.4. Notes for Environmental Educators

Our study points to positive aspects of out of school interventions, either short-term or/and student-centered. Especially the acquired knowledge level is encouraging. We cannot compare our intervention with a classroom learning unit, though many other studies see first-hand experience as positive for participants. Similarly, we cannot decide whether the knowledge increase occurs from learning at workstations, which allows the participants an intense confrontation with the issue, or the out-of-classroom situation. However, our program and/or the participants' age contributed to an increase in the three dimensions of knowledge. Our present study supports the intent to short-term outreach interventions in a student-centered framework: Not only for pupils but also for teachers, a short-term learning unit might better match tight school schedules. Our results are quite encouraging for environmental education as they relate system, action-related and effectiveness knowledge with each other within one educational module. All three types of knowledge are regarded as an important basis to influence general ecological behavior, which must be the final goal of every educational approach in environmental education. Based on the model of the three dimensions of knowledge and our results, even short-term educational programs have the potential to influence conservation behavior. For the protection of water even more of these learning programs should be developed. In many areas a change in human behavior is already necessary to protect our most important resource.

Acknowledgments

This study was supported by the Federal Ministry of Education and Research (BMBF): "RiSKWa-Verbundprojekt PRiMaT: Präventives Risikomanagement in der Trinkwasserversorgung" (#02WRS1279L). We specifically thank the field centre "Jugendwaldheim" of the National park Bavarian Forest as well as all teachers and pupils involved in this study for their cooperation. Additionally, we are very thankful to Michael Wiseman for discussion on earlier drafts of the manuscript.

Author Contributions

This study is part of the PhD thesis of Christian Fremerey supervised by Franz X. Bogner.

Conflicts of Interest

The authors declare no conflict of interest.

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