

## Streamside science

*Tailoring watershed education to meet the needs of teachers*

by Nancy O. Mesner and André D. Walker



Educational programs, especially at a secondary level, can significantly impact adult attitudes and concerns for the environment (Palmer 1993). Orr (1992) suggests that quality education programs require a pedagogical approach that integrates both content knowledge and practical experience. Buethel and Smallwood (1987) found that teachers at all levels and in all subjects influence their students' environmental attitudes and that what they teach is influenced by what they know and what they value. In addition, those teachers with a better understanding of environmental issues appear to be more effective in helping their students become more aware of their environment.

Utah State University Extension's Water Quality Program uses stream monitoring techniques to teach about water pollution and watershed functions. Our programs reach over 5,000 youth each year with activities ranging from one hour to all day. In an attempt to reach more young people, we also train teachers to use our activities; however, classroom adoption of these activities has remained limited to those teachers with a special interest in water or outdoor education.

Through informal discussions with teachers, we became aware of probable barriers to wider use of our activities by educators, the most significant being the increasing need for teachers to focus on core curriculum standards with end-of-year testing in mind. This paper discusses the strategy we implemented to reach our overall goal of helping citizens make the link between their actions and the subsequent effects on water quality, specifically by increasing the use of water quality educational materials in schools.



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## METHODS AND MATERIALS

First, we assessed the barriers teachers experienced in using our existing materials. Based on these findings, we developed new materials and a strategic approach that we felt would address the identified needs of teachers. We then evaluated the use and the effectiveness of our materials in improving student knowledge of water quality and watershed science. We conducted this assessment as a means of improving the materials and to make the materials more acceptable within the education community (Thomas 1989).

In developing improved materials for teachers, we were particularly interested in modifying our *Utah Stream Team* manual (Geiger and Mesner 2002), which is an extensive and detailed stream monitoring program developed for formal and informal educators. The *Utah Stream Team* manual provides background and resources for designing and implementing a stream monitoring program but does not include specific lesson plans. We solicited the input and active involvement of the Utah State Office of Education (USOE) science coordinator concerning our existing materials and requested his support in further pursuing the project. The coordinator determined that our existing materials were founded in good science and best fit a ninth grade earth systems science course required of all Utah students.

With the USOE's assistance, we formed a focus group of three teachers and two district science coordinators to help identify teacher needs and constraints and also to review the materials we developed. Participants in the focus group met twice in extended face to face meetings and were contacted individually throughout the project. We also solicited ideas and feedback on our draft materials from our partners in water resource management and education across the state.

At our first focus group meeting we reviewed the *Utah Stream Team* manual and identified where the water quality education and monitoring activities could fit into the core curriculum. Based on this

information, we developed a set of specific lesson plans for Utah's ninth grade earth systems science course using stream monitoring activities, which we collectively titled *Stream Side Science*. During development, members of the focus group reviewed materials and commented on the relevance of the lesson plans, clarity of instructions, format, age appropriateness, and content. The materials were also reviewed by water resource specialists and university researchers for scientific accuracy.

At the final focus group meeting, participants were asked to confirm that the curriculum would meet the needs of teachers, correlate specific lesson plans to the Utah core curriculum standards and objectives and intended learning outcomes for ninth grade earth systems science, and discuss any suggested changes following teacher review and pilot testing.

We evaluated the completed curriculum by testing 517 students before and after they were taught one or more of the lesson plans in the curriculum. The intent was to measure changes in knowledge of water quality concepts and also to determine whether this curriculum could be used to improve end-of-year test scores. The tests were developed in coordination with the USOE assessment specialist and a panel of six academics and general citizens who judged the content validity, readability, and age appropriateness of the questions. A multiple choice testing format was used to most closely replicate the end-of-year testing that is mandatory in Utah classrooms.

Seven ninth grade earth systems science teachers from schools within 150 miles of Salt Lake City volunteered to participate in testing the materials. None of the participating teachers had ever used the *Stream Side Science* curriculum before, which prevented bias from prior experience with the activities. Teachers were asked to give their students our previously written 10-question pre-test within two weeks prior to teaching an activity from the *Stream Side Science* manual and give the same

10-question post-test within two weeks of completing the activity. The teachers were also asked to fill out a general survey related to their background, their interest and knowledge of water quality, and the extent to which they used the *Stream Side Science* activities.

Teachers were asked to use any or all of five identified lesson plans from the *Stream Side Science* manual. The lesson plans encompass physical, chemical, and biological components of aquatic systems and their interactions, and management implications. All but one plan incorporate water quality testing or biological sampling. The individual lessons are as follows:

- **What's in the Water?** Students measure four abiotic factors (pH, dissolved oxygen, turbidity, and temperature) and learn how these factors are influenced by external conditions such as location, land use, and pollution.
- **Who Lives in the Water?** Students explore diversity and adaptation to aquatic environments by observing aquatic macroinvertebrates collected in a stream.
- **When Things Heat Up.** Students measure temperature and dissolved oxygen, and learn how these two abiotic factors affect each other and are affected by other physical and biological conditions in a stream.
- **The Nitrogen Cycle.** Students diagram the nitrogen cycle following a teacher-led discussion and measure nitrogen in water samples collected from different sources to better understand human impacts on the global nitrogen cycle.
- **That's Predictable.** Students research and report on ecosystem changes that may occur as a result of changes in abiotic or biotic factors such as drought or the construction of a dam.

For each lesson plan, we compared absolute changes in pre- and post-test scores using matched paired t-tests. One of the lesson plans, "What's in the Water," was used by all teachers in the study. We



correlated test score changes from this lesson plan with external factors, such as student gender, school location, teacher experience and background, and other teaching approaches. Test results from this lesson plan were also evaluated for the effect of school setting (rural versus suburban versus urban) and the number of lessons taught to a class using a Tukey test.

## RESULTS AND DISCUSSION

**Development of Activities.** Our focus group identified six barriers to using watershed and water quality resources:

1. Teachers need to focus on core curriculum standards with end-of-year testing in mind.
2. A majority of teachers are not confident in their knowledge of water quality science.
3. Teachers want specific lesson plans, not a manual from which they have to pull together their own lessons.
4. Teachers may be unwilling to take students to a stream setting because of safety concerns.
5. Teachers are limited financially and may be unwilling to use a curriculum that requires additional materials.
6. Teachers may have a limit on the number of field trips allowed each year.

To address these barriers, the following features were incorporated into the *Stream Side Science* manual.

All activities are aligned to the Utah state core curriculum for ninth grade earth systems science and the corresponding intended learning outcomes. The content of the 11 *Stream Side Science* lesson plans are based upon watershed science, with three lesson plans focusing on water chemistry, four lesson plans focusing on aquatic biology and riparian vegetation, three focusing on interactions between different biological and physical elements in aquatic ecosystems, and one focusing on global water reservoirs. In total, the curriculum addresses three of the six standards

for this semester-long course, including 14 objectives and 35 intended learning outcomes. The lesson plans are formatted to lead teachers through the activities easily.

Safety concerns are explicitly addressed in the appendix of the manual and also in each lesson plan when necessary. The activities use low-cost monitoring equipment. We include supplier information for all monitoring materials and also advice on constructing equipment and finding low cost alternatives. The manual also contains tips on how to “bring the stream to the classroom” for those who have a limited field trip budget or limited access to natural streams or other waterbodies.

**Distribution and Teacher Training.** In September of 2004, the USOE assisted in distributing the *Stream Side Science* manual to all 285 of Utah’s ninth grade earth systems science teachers. The teachers also received a letter from the state science coordinator endorsing the curriculum. Since then, over 500 manuals have been distributed to resource specialists, nonprofit agencies, state and federal agencies, other teachers, and interested parties throughout Utah as well as surrounding states.

At the advice of the USOE and in response to focus group concerns, we developed a strategy for ongoing support for teachers using this curriculum, including an eight-hour training. This meets the requirement for one-half university graduate level credit or eight relicensure points. To further address monetary limits of teachers, we obtain financial support so that many trainings are free for participants, and we also pay for the substitute teachers for those attending. The workshops teach basic watershed and water quality science,

and watershed specific issues in Utah. Teachers learn and practice water quality tests, learn how to interpret the results, and how to adapt the activities for individual classroom situations. Between September 2004 and December 2006, 94 teachers have attended *Stream Side Science* workshops and we continue to offer additional workshops each year.

**Change in Student Knowledge.** Because teachers were allowed to choose which lesson plans they used, the number of students tested for the five lessons varied between 161 and 517. In all cases, student testing demonstrated a significant increase in knowledge attributable to the use of the *Stream Side Science* lesson plans and activities. Pre- and post-testing found a significant, although relatively small, knowledge gain by students in all five of the lesson plans tested (table 1).

We were able to further explore differences in student test scores and the potential impact of external factors for one lesson only, “What’s in the Water?” This lesson plan was taught by participating teachers to a total of 517 students.

The total number of students tested was almost evenly split between males and females. Although male and female pre-test scores were almost identical, males had a significantly greater score increase (table 2).

Teachers were asked to characterize their school setting as rural, suburban, or urban. Based on these self-identified categories, rural students had a higher initial score than the other students but showed a smaller increase between pre- and post-tests (table 3). As a result, there was no significant difference between school set-

**Table 1**

Pre- and post-test score means for individual lesson plans (scores on a range of 0 to 10 points).

Lesson	Number of students	Mean pre-test score	Mean post-test score	p-value
What’s in the Water?	517	3.57	4.84	<0.0001
Who Lives in the Water?	320	3.53	5.16	<0.0001
When Things Heat Up	161	4.20	5.78	<0.0001
The Nitrogen Cycle	162	3.52	4.58	<0.0001
That’s Predictable	162	4.64	5.32	<0.0001

**Table 2**

Effect of student gender on test score increase (scores on a range of 0 to 10 points).

Predictors of knowledge increase	Number of students	Pre-test mean	Mean score increase	Percentage increase	p-value
Female student	254	3.58	1.06	10.6%	0.027
Male student	243	3.57	1.49	14.9%	

**Table 3**

Effect of school location on test score increase (scores on a range of 0 to 10 points).

Predictors of knowledge increase	Number of students	Pre-test mean	Mean score increase	Percentage increase	p-value
Urban	80	3.09	1.46	14.6%	0.220
Suburban	278	3.54	1.32	13.2%	
Rural	64	4.11	0.86	8.6%	
Travel to stream site on foot	199	3.81	0.81	8.1%	<0.0001
Travel to stream site by car or bus	223	3.29	1.69	16.9%	

**Table 4**

Effect of teacher characteristics on test score increase (scores on a range of 0 to 10 points).

Predictors of knowledge increase	Number of students	Pre-test mean	Mean score increase	Percentage increase	p-value
Teacher with master's degree	135	3.65	0.79	7.9%	0.003
Teacher with bachelor's degree only	382	3.50	1.44	14.4%	
1 to 5 years teaching experience	223	3.29	1.69	16.9%	0.009
>5 years teaching experience	178	3.74	1.11	11.1%	
High interest in water quality	331	3.43	1.45	14.5%	0.010
Medium interest in water quality	186	3.74	0.94	9.4%	

tings. When urban and suburban schools were combined and compared to the rural schools, the urban and suburban students had a significantly greater test score increase than the rural students.

We also evaluated the effect of transportation mode to the field site (table 3). The teachers identified how students traveled to the stream site, which was also considered an indicator of distance from the school to the stream. Students who walked to the stream had higher pre-test scores but a significantly smaller increase in their post-test scores. The absolute post-test scores of both groups were quite close (mean of 3.62 compared to 3.98).

Teacher education, experience, and general interest in water all significantly affected test score increases (table 4). Students of teachers with a master's degree had slightly higher pre-test scores but a smaller increase in their post-test scores.

This resulted in final scores that were quite similar, although the increase was significantly greater for teachers with bachelor's degrees only.

A similar effect was seen when comparing the score increases of students with relatively new teachers (one to five years experience) and more experienced teachers. In this case, the students of more experienced teachers had higher initial scores but a smaller increase, again resulting in similar final scores but a significant difference in score change. Teachers who identified themselves as having a high interest in water had students with a significantly greater test score increase.

We were interested in how teaching approaches might affect test scores (table 5). Of the total 517 students compared in this analysis, 196 were taught "What's in the Water?" 87 were taught two of the five lessons, and 162 were taught all five

lessons. A significant difference was found in test scores between those students who were taught one lesson versus five.

Team teaching appeared to have a beneficial affect on student score increases. Students of teachers who worked alone had a higher pre-test score mean, but students of teachers who worked together had score increases approximately two times greater. Students who were taught the materials all in one day also had a significantly greater score increase than those who received the information over multiple days.

Teacher time spent in preparing lessons and in teaching the lessons both resulted in significant student score increases. In both cases, students of teachers who spent more time on preparation and more time on the activities had lower initial scores but significant increases. Although we expected that when teachers reviewed test

**Table 5**

Effect of teacher approaches on test score increase (scores on a range of 0 to 10 points).

Predictors of knowledge increase	Number of students	Mean pre-test score	Mean score increase	Percentage increase	p-value
1 activity used	196	3.84	1.02	10.2%	0.004*
2 activities used	87	3.89	1.39	13.9%	
5 activities used	162	3.33	1.75	17.5%	
Work with other teachers	337	3.34	1.54	15.4%	<0.0001
Work alone	180	3.94	0.76	7.6%	
Teach activities as a unit (1 day)	321	3.58	1.42	14.2%	0.038
Teach activities over multiple days	196	3.48	1.02	10.2%	
<5 hours teacher preparation time	336	3.68	1.04	10.4%	0.001
≥5 hours teacher preparation time	181	3.24	1.70	17.0%	
<5 hours spent on activities	275	3.83	0.93	9.3%	<0.0001
≥5 hours spent on activities	242	3.24	1.66	16.6%	
Test procedure not reviewed before	114	3.44	1.25	12.5%	0.897
Test procedure reviewed before	403	3.57	1.28	12.8%	
Discussion questions not used	206	3.43	1.04	10.4%	0.003
Discussion questions used	311	3.33	1.62	16.2%	

\* Between 1 activity and 5 activities.

procedures with their students before the field day there would be greater comprehension by the students, test scores in these cases did not significantly increase. We also hoped that providing study questions to facilitate student discussion would increase student comprehension and retention. Students of those teachers who used the questions provided in the lesson plan had a significant increase of test scores.

## SUMMARY AND CONCLUSIONS

*Stream Side Science* is a curriculum of 11 lesson plans developed specifically for a physical science class required of all ninth graders in Utah. Because we developed these lessons with barriers to teacher adoption in mind, they have been very positively received by these teachers. Identification of specific barriers and suggested solutions by our focus group resulted in a highly usable manual for working teachers. Teachers were reassured by the official support of the Utah State Office of Education in the development and distribution of this curriculum.

One of the barriers we identified to adoption of our water quality education materials was a lack of knowledge of water quality and watershed science.

We feel that the workshops we have provided for teachers using *Stream Side Science* have been essential to the success of this curriculum. Our results and other studies have indicated that teachers need science equipment to make a successful outing (Simmons 1993). We have provided check-out trunks of materials (containing all the test kits needed for the field data collection) in each county extension office. We are also developing supplements for specific watersheds in the state. These provide more detailed maps, localized background material, local contacts, and ideas on monitoring locations.

Each of the five specific lesson plans tested showed that students had a significant increase in knowledge of water related issues. In all cases, however, the score increases were relatively small. Typically the mean student scores increased about 1.5 points out of 10 (figure 1).

We designed our tests to closely approximate questions that students would be asked in end-of-year testing. Our results suggest that the use of *Stream Side Science* lesson plans will, in fact, improve end-of-year student test scores.

Much of the success of educational experiences results from factors that are not directly related to the curricular mate-

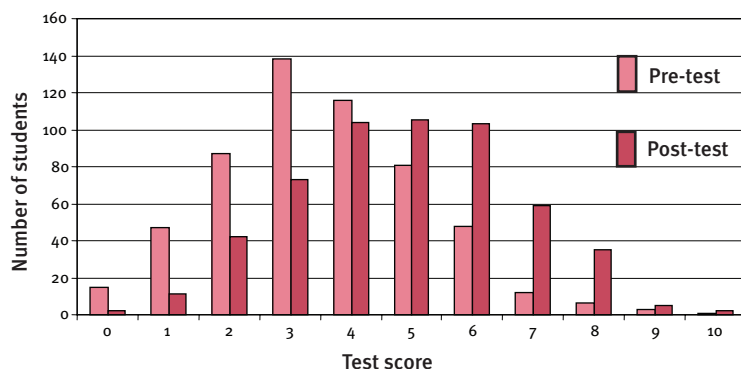
rials. Our assessment of some of these factors showed some interesting trends. Rural school students had a significantly smaller increase in test scores than those from urban and suburban schools. This may be explained in part by the higher initial scores of the rural students. The rural students appear to have had a greater initial awareness of potential impacts to water quality from various rural activities, ranging from cropping practices and dairy or other animal operations to living closer to open stream and lakes.

Students who drove to stream sites had a significantly greater increase in test scores than those who walked. As with the rural students in the previous comparison, this difference may be explained in part by the higher initial test scores for students within walking distance of a stream. These students appear to have had a greater initial awareness of streams and other related issues. Another possible explanation is that driving to a field trip is expensive and uses limited results, so those teachers may teach these materials more thoroughly. There could also be more accountability placed on the students when traveling on a formal off-campus field trip, rather than walking to a creek near the school.

Students of teachers with self-identified

**Figure 1**

Pre- and post-test scores for “What’s in the Water” lesson.



high interest in water quality had greater score increases. Against our expectations, however, score increases were smaller for students of teachers with master’s degrees than for those of teachers with bachelor’s degrees. This same trend is seen when we looked at the effect of teaching experience. Score increases were smaller for students of teachers with more than five years teaching experience than for those with less experienced teachers. It is possible that younger teachers may be more willing to try new activities and take their students out into the field, or they may be more accustomed to using hands-on activities.

The study also revealed the value of teaching more than one of the *Stream Side Science* lessons and using some of the additional features of the lesson plans. Score increases were greater when teachers used all five lessons compared to those who used just one. This suggests that student learning increases when multiple aspects of water science are taught. Students also benefited from classroom discussion of the activities, using the discussion question provided with the lesson plans.

Based on our assessment of *Stream Side Science*, we feel that the multiple activities in this curriculum help the students make connections between water related topics and improve their general understanding of related concepts. In addition to meeting the needs of a specific group of teachers in Utah, this resource has proven useful for students of many ages. The activities have

been used in multiple settings by informal educators as well. Our hope is that increased exposure of high quality educational materials that help students link their activities and land uses with water quality will result in long-term awareness and protection of these resources.

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