Students' Attitudes towards Science in Classes Using Hands-On or Textbook Based Curriculum

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The development and use of hands-on science curricula in elementary school has been a major reform effort of the past two decades. But research on the results of these efforts has been ambiguous. A recent study by Pine et al (2006) reported on the results of a large-scale assessment of the science knowledge and skills of students who learned with hands on science and students who learned with textbook. Their results showed generally low scores on performance assessments for both types of students with only a minor advantage for the hands-on students (on one of four assessments). This paper looks at some additional data from that study on students' attitude towards science and science topics. We find that students in the hands-on classes were generally more favorable to science and had a better understanding of the nature of science than students in textbook classes. The differences in attitude do not correlate significantly with test scores.

Introduction

Much of the elementary science education reform of the last decade has focused on engaging students in scientific inquiry though the use of hands-on curriculum in school. It is a major focus of the National Science Education Standards (National Research Council, 1996) and has been advocated in numerous documents (e.g. American Association for the Advancement of Science, 1990; National Research Council, 2000). The National Science Foundation assisted in the development of curriculum materials such as the *Full Option Science System* (FOSS) and *Insights* to provide hands-on materials for all the topics in the standards. While there is a great deal of research to show that teaching science through inquiry can be effective on a limited scale, there is little data available on the success of these reforms once they spread to the larger school community. A recent large-scale evaluation of hands-on science teaching by the Caltech

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Pre-college Science Initiative (CAPSI) looked at the effect of the typical use of hands-on science curricula (Pine, Aschbacher, Roth, Jones, McPhee, Martin, Phelps, Kyle & Foley, 2006). This study identified schools which predominantly used hands-on science curricula and others where textbooks were used and then assessed students' knowledge and skills in the 5th grade. This study showed only very minor advantages for hands-on science curricula compared to textbook science curricula. But the students' knowledge and skills are only part of the impact of the curricula. Students' attitudes about science may also play an important role in future success and persistence in science. This paper looks further into the Pine et al. (2006) data to see how students' attitudes about science varied across the different schools.

Background

Most elementary schools use textbooks to teach science (when science is taught at all), but hands-on science curricula have become increasingly popular over the last two decades (cite). Hands-on science typically engages students in research activities in the classroom. Complete curricula of hands-on activities have been developed to effectively replace the use of science textbooks in elementary classroom: Full Option Science System (FOSS; Delta Education), developed at the Lawrence Hall for Science (at the University of California, Berkeley), Science and Technology for Children (STC; Carolina Biological Supply Company), developed by the National Science Resources Center (a joint enterprise of the National Academy of Sciences and the Smithsonian Institution), and Insights (Kendall/Hunt). Other curricula offer a combination of textbook and hands-on activities (e.g. Scott Forseman Science). The hands-on activities provide students with opportunities to engage in exploration and sense making with the science content.

Researchers on elementary science reform emphasize the need for students to engage in scientific inquiry (Driver et al., 1994; Harlen, 2004). Engaging students in inquiry can provide a powerful learning experience where students not only learn about science content but also gain reasoning and research skills. Students come to understand the nature of scientific problem solving as the pursuit of meaningful questions through the use of procedures that are thoughtfully generated and evaluated (Magnusson & Palincsar, 1995). The hands-on science curricula (e.g. FOSS, Insights) also describe their materials as promoting scientific inquiry. The positive value of science teaching through inquiry is nearly universal in the literature, but the implementation of this pedagogy in classrooms has been problematic.

Critics of the reforms have pointed out that the implementation of hands-on curricula can err either on the side of too much or too little guidance. Research on high-school science labs shows that highly structured activities may teach students to simply 'follow the recipe' and result in little meaningful learning of content or research methodology (NRC, 2005). In the other extreme, if teachers provide too little guidance, the activity becomes "discovery learning" which has not been very effective in previous studies (Mayer, 2004). Observations of hands-on science have indicated that some teachers do not fully implement the curriculum as it is designed (Aschbacher & Roth, 2002). Instead, some teachers have the students conduct hands-on activities without the preparation, analysis and reflection that is often called for. Without having detailed knowledge of the actual implementation of the hands-on curricula, it is not possible to tell how much inquiry is happening. For this reason we will refer to "hands-on science curricula" and note that inquiry is likely to be an element of some of this teaching.

Research on the effectiveness of hands-on science curricula tends to show a positive effect for small tightly controlled studies. Studies where researchers closely monitored the curriculum (often involving technology) have resulted in more science learning (Kracjik et al, 1998; Lehrer, Schauble, Carpenter & Penner, 2000; White & Frederiksen, 1998; Young & Lee, 2005). Research in the 1970s and 1980s showed an advantage for hands-on science (Bredderman, 1983; Shymanski, Hedges & Woodworth, 1990). Stohr-Hunt's (1996) analysis of test data and teachers' self report of hands-on frequency show very small increases in scores for students who had more hands-on experience. More recent studies have looked at hands-on science implementation within a single district. Research from El Centro Schools shows district reading and writing scores improved after the adoption of hands-on science curricula (Amaral, Garrison, & Klentschy, 2002) and that when teachers have professional development in Scaffolded Guided-Inquiry students learning improves (Vanosdall, Klentschy, Hedges & Weisbaum, 2007). Schymansky, Yore & Anderson (2004) report that added professional development for teachers did not lead to gains in science scores or attitudes about science. The use of hands-on curricula continues to expand, but textbook science is still generally treated as the norm. We are not aware of any research that establishes that textbooks are better than the absence of science education. Many elementary teachers or schools choose a third option which is to teach little or no science, choosing instead to focus on math and language skills which are more heavily tested.

The CAPSI study was a large scale assessment of the difference between hands-on and textbook based science education in what can be considered general use of hands-on curricula. The CAPSI study identified 40 schools where science was taught either primarily with a textbook or primarily with hands-on activities. These classes came from six school districts in three states and used a variety of textbooks (e.g. Scott Foresman) and hands-on curricula (e.g. FOSS, Insights). The classes were selected to balance both the type of science curriculum used and the socio-economic status (SES) of the schools. Fifth grade students at each school (N = 972 students) were assessed with multiple choice and performance assessments of science knowledge as well as a survey and cognitive ability test. The assessment of fifth grade students was designed to measure the cumulative effect of several years of either textbook or hands-on science. Although some districts had a coherent science education policy to use the kits, the policy did not appear to be strictly adhered to. Interviews with teachers suggested that the application of the curriculum had a good deal of variation even within districts with a clear policy.

Pine et al (2006) found that students in the hands-on and textbook groups performed similarly on the multiple choice test and performance assessments (one of four performance assessments showed a significant advantage for the hands-on students). Table 1 summarizes these results for the hands-on and textbook classes which fail to support either the hypothesis that textbook classes would do better on the multiple choice test, or that hands-on classes would do better on the performance assessments. They concluded that students in both groups performed poorly on average and there was not a large advantage for the hands-on students.

> "Graphs such as this have been examined for each assessment, and typically yield similar low levels of performance on the most cognitively demanding items. Just as here, there were significant SES differences but little if any difference between hands-on and text book students." p. 474

	Multiple choice	Short performance assessments		Long performance assessments	
	MC	SPA1	SPA2	LPA1	LPA2
Hands-on Classes (HO) (N=20 classes)	6.16 (0.09)	3.98 (0.15)	4.04 (0.15)	4.61 (0.12)	**5.39*** (0.11)
Textbook Science Classes (TX) (N=20 classes)	6.19 (0.09)	3.68 (0.15)	4.24 (0.17)	4.64 (0.12)	**4.99*** (0.11)

Table 1: Summary of results of Pine et al (2006) p. 476. Only one of five measurements show significant difference between the hands-on and textbook students. (*HO-TX difference is significant $p<.05$)

These findings are discouraging for the hands-on science advocates. Pine et al (2006) argue that the strong correlation between the science scores and the cognitive ability scores show that the science instruction did not have a strong effect. They call for improved professional development for teachers who are using hands-on science.

Teaching science with hand-on inquiry may have more effects that student achievement. A number of papers have linked hands-on or inquiry teaching to changes in students attitudes (Kyle, Bonnstetter, McCloskey, & Fults, 1985; Chang & Mao, 1999; Shymanski, Yore, Anderson, 2004). Many studies report that inquiry activities resulted in greater interest in science and motivation to do science. One study, Gibson & Chase (2002) reported that inquiry activities not only led to more interest in science but that this interest persisted long after the inquiry intervention was over. The thought is that if students are more interested in science because of inquiry experiences, they may be more likely to study science in the future and persist in science classes. Nieswandt (2007) did not find direct effect of attitudes on achievement but found an indirect connection in longitudinal data. Interest in science has been linked to future enrollment in science courses and pursuit of science related careers (Sinclair, 1994).

Data on students' attitudes was collected as part of the CAPSI study, but not reported in the Pine et al. (2006) paper. This paper looks at the attitude data from that study to see how the previous findings on students' attitudes about inquiry science are supported in the hands-on and textbook science study. In particular we look at how the two groups compared in their interest in science and their understanding of the nature of science and how the attitude about science interacts with the content scores.

Methods

As described in Pine et al (2006), schools were identified where science was taught primarily using hands-on curricula (HO schools) or primarily with textbooks (TX schools) and science teaching was a significant part of the curriculum from grades 2-5. Students in these schools likely had several years of either hands-on or textbook science. From these schools 41 fifth-grade classrooms (N=955) were selected for the study to balance for both science curriculum (HO or TX) and SES (LO >50% of students eligible for food subsidies or HI <50%). Each fifth grade classroom was observed twice to see how science was being taught and the teachers were interviewed about their instruction.

SES / Curriculum	Low SES	High SES	Total
Hands-On	208	272	480
Textbook	259	216	475
Total	467	488	955

Table 2: Numbers of students who completed the science attitude survey by class curriculum type and socio-economic status (SES). Low SES is defined as >50% of students eligible for subsidized lunches.

At each classroom, students were given a number of assessments including a cognitive abilities test, a multiple choice science test, two short performance assessments and one of two long performance assessments. The multiple choice test included released items from TIMSS and NAEP assessment and was designed to assess students knowledge of science concepts and vocabulary. The performance assessments were designed to measure students' ability to draw conclusions from observations and testing. The entire battery of assessments took over five hours of class time over three days. All of the assessments were administered by researchers using the same protocol in all classes.

The CAPSI Science Interest Survey (SIS) consisted of 22 questions about students' attitude and beliefs about science. Because of time constraints during data collection, the SIS was short (20 minutes) and relied heavily on Likert-scale questions with only a few free response questions. The survey asked students about their science experiences, how they rate different subjects and some questions about the nature of science[2]. Figure 1 shows a sample of these questions. The survey was too brief to be effectively validated. In analyzing the data, a coding key was developed for the free response questions and coders where trained until they achieved a 90% agreement.

[2] Some nature of science questions were taken from Songer & Linn (1991).

A) Which subjects to do like to study most in school?

Rank them from *like a lot* (5) to *don't like* (1):

Science	like it a lot	**5**	**4**	**3**	**2**	**1**	don't like it at all
Social Studies (history)	like it a lot	**5**	**4**	**3**	**2**	**1**	don't like it at all
Math	like it a lot	**5**	**4**	**3**	**2**	**1**	don't like it at all
Reading	like it a lot	**5**	**4**	**3**	**2**	**1**	don't like it at all
Spelling	like it a lot	**5**	**4**	**3**	**2**	**1**	don't like it at all

B) How hard is science for you? (circle a number from 1-5)

very hard **5** **4** **3** **2** **1** easy

C) Do you agree or disagree with the following sentences:

a) "The science in school is not related to my everyday life."

(circle one) **agree** **disagree**

b) "Understanding scientific ideas is more important than memorizing facts."

agree **disagree**

c) "Science is too complicated for most students to understand."

agree **disagree**

d) "Science is more important for boys than for girls."

agree **disagree**

e) "The science principles in textbooks will always be true."

agree **disagree**

Please explain your answer to (e):

Figure 1: Three questions from the CAPSI Science Interest Survey (SIS)

Results

Science is a popular topic in many elementary schools. In both the hands-on and textbook classes, students rated science higher than any other subjects (e.g. math, reading). All students ratings on a 5 point scale showed science averaged to 4.33 for all students compared to social studies (3.34), math (3.92), reading (3.98). The type of curriculum did make a difference in how students rated liking science. Students in the hands-on classes rated science higher (4.44) than those in the textbook classes (4.23). This difference is significant ($t(970) = 3.55$, $p<.001$) but small, possibly due to ceiling effects of the scale. Looking at the same data in a different way, a higher number of students rated science as their favorite subject in hands-on classes (69%) than students in textbook classes (56%).

Ratings for liking topics:	Science	Social Studies	Math	Reading	% students rating science highest
HO HI (N=272)	4.33 (0.90)	3.18 (1.48)	3.79 (1.41)	3.81 (1.29)	67%
HO LO (N=208)	4.57 (0.78)	3.44 (1.41)	3.97 (1.37)	4.25 (1.09)	74%
TX HI (N=216)	4.19 (1.02)	3.46 (1.41)	3.77 (1.44)	4.01 (1.19)	55%
TX LO (N=259)	4.25 (0.99)	3.46 (1.31)	4.16 (1.27)	3.89 (1.17)	57%
All HO (N=497)	**4.44*** (0.85)	3.30 (1.43)	3.87 (1.38)	4.00 (1.23)	**69%***
All TX (N=475)	**4.23*** (1.01)	3.46 (1.35)	3.98 (1.36)	3.95 (1.18)	**56%***
All Students (N=972)	4.33 (0.94)	3.38 (1.40)	3.92 (1.37)	3.98 (1.20)	63%

Table 3: Students ratings for liking science and other topics. Data are reported for hands-on (HO) or textbook and high (HI) or low (LO) SES (* p<.005)

Students' preferences also varied on the type of science that is most interesting. Students in hands-on classes were more likely to prefer physical science and less likely to favor learning about space (see Table 4). It is probably not surprising that hands-on students would have less experience with space – a topic that can be difficult to study in a hands-on fashion. Students in hands-on classes rated science as being less hard than students in textbook classes (HO mean 2.14 sd 1.12, TX mean 2.5, sd 1.16, $t(977) = 4.48$, $p<.001$). Despite these differences, there were no significant differences in the number of students who indicated they would like to be a scientist (18.9% of hands-on and 18.7% of textbook students). Surprisingly, in hands-on classes we see much higher ratings by low SES (HOLO) students than high SES students (HOHI) – and no similar trend in textbook classes. For example HOLO students ratings for physics (mean 4.51 sd .81) are much higher than HOHI students (mean 3.99 sd 1.13, $t(474)=5.60$, $p<.001$), while textbook students show no similar gap (TXLO mean 3.86 sd 1.28; TXHI mean 3.84 sd 1.07).

Ratings for liking topics:	Physics	Biology	Chemistry	Space	Earth Science
All HO (N=497)	**4.20*** (1.05)	4.33 (1.02)	**3.97*** (1.22)	**4.44*** (0.95)	4.46 (0.93)
All TX (N=475)	**3.85*** (1.19)	4.38 (0.96)	**3.76*** (1.20)	**4.63*** (0.78)	4.41 (1.01)
All Students (N=972)	4.03 (1.13)	4.36 (0.99)	3.87 (1.22)	4.53 (0.88)	4.44 (0.97)

Table 4: Students ratings for liking different science topics (* p<.005)

Students' conceptions of what and how they were learning also varied. When asked to name science topics they had studied that year, 61% of textbook students named 3 or more topics, compared to only 27% of the hands-on students. Either student in textbook classes are able to cover more topics or the textbook students are more aware of the subjects that they are studying. Both groups reported doing experiments as part of science lessons (HO 94%, TX 87%) but many more textbook students reported using a science textbook (HO 42%, TX 92%). We might have expected these numbers to be closer to 100% of hands-on classes using experiments and 100% of textbook classes using textbooks. The variation may be due to students transferring, teachers going against district guidelines or simply students misunderstanding the questions. The high numbers of textbook students who have experience with experiments and hands-on students who use books shows that a good deal of blending of curricula was taking place even in the selected schools.

Students were also asked how much help they receive on science from their parents. We had expected that textbook students would have more help because they are able to bring the textbooks home where most of the hands-on activities are done in the classroom. Contrary to this hypothesis, students in hands-on classes report receiving slightly more help than students in textbook classes ($t(972)= 2.11$; $p=.035$).

Nature of Science

In terms of students' conceptions of science, few differences are evident between the groups (only seven SIS questions address nature of science issues). Slightly more textbook students found science to be relevant to their everyday lives (HO 55%, TX 64%). Both groups split on the question of whether it is better to memorize or understand scientific ideas (HO 51%, TX 51% say understanding is more important). Most students disagreed with this statement that "science is too complicated for most students to understand" (HO 69%, TX 67% disagreed). In some questions, students in textbook classes seemed to the put the same or more emphasis on experimentation than students in hands-on classes. Both groups gave similar descriptions to the question "What does a scientist do?" textbook students indicated experimentation more often than hands-on students (HO 20%, TX 25%). Students' responses to the question about what you should do to become better at science both groups were equally likely to mention experimentation (HO 20%, TO 22%) but not reading (HO 7%, TX, 18%). On the question of changes in science ("Why do science textbooks change?") only 7% of hands-on and 9% of textbook students mentioned improvements in our understanding of nature ("people make mistakes" was a more common response). This question is designed to assess whether students see science as a static body of knowledge or ideas that are subject to change (Songer & Linn, 1992). But this question may be too abstract for 5th grade students.

Gender Effects

Pine et al (2006) report that only one of the performance assessments showed any large gender effect - girls did better than boys on one long performance assessment. In attitudes towards science we observe a mild gender effect for liking science (girls mean 4.28 sd 0.95, boys mean 4.39 sd 0.92, $p = .057$) and similar trends showed up for the different science topics (Table 5). Girls in hands-on classes favored biology while boys in both groups were more positive towards physics and earth science. There is not a strong interaction between gender and type of science curriculum.

Ratings for liking topics:	Science	Physics	Biology	Space	Earth Science
HO Girls (N=255)	4.41 (0.81)	**4.06*** (1.10)	**4.46*** (0.89)	4.43 (0.92)	**4.34*** (0.99)
HO Boys (N=241)	4.46 (0.89)	**4.35*** (0.96)	**4.19*** (1.13)	4.44 (0.98)	**4.59*** (0.85)
TX Girls (N=249)	4.14 (1.06)	**3.65*** (1.22)	4.42 (0.96)	4.58 (0.82)	**4.27*** (1.11)
TX Boys (N=226)	4.31 (0.94)	**4.07*** (1.10)	4.34 (0.97)	4.68 (0.75)	**4.57*** (0.87)
All Students (N=972)	4.33 (0.94)	4.03 (1.13)	4.36 (0.99)	4.53 (0.88)	4.44 (0.97)

Table 5: Students ratings for liking science and different science topics (Comparison of boys and girls' means is significant* p<.005)

Correlations with outcome data

According to Pine et al (2006) the primary co-variate with the students' scores on the written and performance assessments was students' score on a test of cognitive ability and the SES of the students' school. Students' ratings of how much they like science is not strongly correlated with scores on the written or performance assessments. Table 6 shows the correlations between the ratings for liking science and thinking that science is hard with the multiple choice and performance assessments. Some of these correlations are statistically significant, but none of the correlations is greater than r=0.2 suggesting that the students attitudes towards science are not strongly correlated with performance on the content assessment

	Multiple choice	Short performance assessments		Long performance assessments	
	MC	SPA1	SPA2	LPA1	LPA2
"like science" rating All students	-.01	-.04	-.09*	-.10	-.03
"science is hard" rating All students	-.15**	-.08*	-.01	-.04	-.12*
"like science" rating HO students	-.03	-.03	-.13**	-.06	-.03
"like science" rating TX students	.01	-.05	-.05	-.16*	-.03
Cognitive Abilities Assessment	.51**	.47**	.28**	.48**	.43**

Table 6: Correlations (r values) between ratings for attitudes questions and science assessments. For comparison, similar correlations are shown for the Cognitive Abilities Assessment (* p<.05, ** p<.005).

Discussion

The findings in Pine et al. (2006) raise the question about weather the money and effort spent on the efforts to promote hands-on science in elementary schools has been well spent. We know that in small, tightly controlled studies, hands-on inquiry curriculum has been very effective at helping students learn science (Kracjik et al, 1998; Lehrer, Schauble, Carpenter & Penner, 2000; White & Frederiksen, 1998). The widely used curricula (e.g. FOSS, Insights) share many of the features of these studies. But the effect of reforms may fade as the reform is spread to hundreds or thousands of classrooms farther from the origins. In the last 20 years the use of hands-on curriculum has spread to many different classes in different places. The CAPSI study looked at the use of hands-on curricula in typical schools where teachers have had limited training on using the kits and little oversight. Observations reveal that teachers do not always follow the curriculum guidelines (Aschbacher & Roth, 2002). The Pine et al (2006) results show that the use of hand-on activities in these classrooms provides only minor gains in science knowledge and skills compared to classrooms that use textbooks. While it is encouraging that hands-on students were just as able to answer the multiple-choice test as well as the textbook students, it is surprising that they were not better at the performance assessments.

The value of the inquiry curriculum is not limited to the scores on these sorts of tests. The CAPSI Science Interest Survey provides a limited assessment of how the hands-on curriculum might affect students thinking about science. The primary difference is that the students in hands-on science schools have a more positive impression of science (although students in textbook classes are very positive as well). Hands-on students are more likely to list science as one of their favorite subjects and find it generally less hard than textbook students. This positive affect is not connected to an interest in science careers, but may encourage students to take more science classes in the future in order to keep open the option of pursuing a scientific career. This may lead to a delayed effect on student learning as Nieswandt (2007) found. Hands-on classes also seem to create a more positive impression of the physical sciences than textbook classes. Physical sciences are particularly important because of the lack of physical science and engineering majors at American universities.

Other hypotheses about the role of hands-on curriculum and students' attitudes towards science are not supported. We do not observe students to have a more sophisticated understand of the process of science. We also do not see a connection between the science attitude questions on the SIS and the students' scores on the science content and skills assessments. If such a connection exists, it will take a more sophisticated survey instrument to detect it.

These findings demonstrate that students' experiences with science are different in the different curricula despite the similarity in the science learning data reported by Pine et al (2006). Without improvements in teacher preparation it seems unlikely that switching to hands-on curriculum will result in science learning gains. But switching to a hands-on curriculum seems likely to improve students' interest in science with no loss of science content. The motivational aspect of the hands-on curriculum may be an important component in increasing the number of students who study science in high school and college. Further research may be able to identify how influential these experiences really are.

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