Time on Text and Science Achievement for High School Biology Students

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Abstract

The conflict between the amount of material to be addressed in high school science classes, the need to prepare students for standardized tests, and the amount of time available forces science educators to make difficult pedagogical decisions on a daily basis. Hands-on and inquiry-based learning offer students more authentic learning experiences with benefits beyond test scores. However, these alternative teaching/learning techniques can be more time consuming than textbook use and exacerbate the conflict between pedagogy and time. The study reported in this article questioned 2712 college Biology students about their high school science experiences. Analyses indicate that the amount of time spent reading biology texts does not influence learning outcomes.

In 1985 the American Association for the Advancement of Science (1998) developed a long-term STEM (science, technology, engineering, mathematics) education reform initiative, *Project 2061*. This initiative became part of a national movement brought on by reports like *A Nation at Risk*, (National Commission on Excellence in Education, 1983) which warned of a national education crisis. *Project 2061* set goals for the systematic advancement of science for all Americans. Educators and researchers alike have tried to find the best methods to meet these goals and improve student learning. In response, there is a great amount of research demonstrating the use of alternative teaching and learning techniques in science classrooms in place of general textbook use. For example, the research based k-8 science curriculum developed at the University of California at Berkeley, FOSS (Full Option Science System) is in use in every state in the United States and it is the first non-textbook based curriculum to make the California State adoption list.

Another example of a widespread reform effort is STS (Science-Technology-Society) etc.), which approaches science education in combination with technology and society and focuses on how the three influence one another in an effort to develop scientifically literate individuals (Yager, Yager & Lim, 2006). The notion that alternative techniques offer some benefit beyond what can be attained by textbook curricula has fueled the creation of instructional kits and manuals as well as computer based lessons and internet sites to aid teachers in implementing alternative techniques in the classroom (Bentley, 2000; Handelsman, et al., 2004; Huber & Moore, 2001; Kennell, 2000; McGlashan, 2007; Science Museum of Virginia, 1999; Stone, 2007). Teachers have been left the task of sorting out the details to determine the best use of precious instructional time.

The influence that alternative methods have on student learning is still unclear. Some research has demonstrated benefits of the various techniques. In 1996, Cofer found students who participated in science service-learning enjoyed science more than those who did not. A study in a high school in Kenya, for instance, demonstrated a significant difference in student understanding of Cell Theory for students who experienced the use of computer-based simulation over those students who did not (Wekesa, Kiboss, & Ndirangu, 2006).

Benefits have also been reported for the use of alternative methods with diverse groups. McCarthy (2005) demonstrated that instructional methods that use hands-on science activities resulted in significant improvement in science learning for students with disabilities. Lee, Buxton, Lewis, and LeRoy (2006) reported that students from less privileged backgrounds and more educational challenges (low SES, English language learners) improved their science inquiry abilities to a level closer to more privileged students when they were exposed to an instructional intervention using inquiry.

When testing is considered, the findings about alternative assessments are mixed. Pine et. al (2006) compared student learning in 41 different classrooms located in 3 different states. The students were either in textbook based classes or classes that used hands-on units including FOSS, STC (Science and Technology for Children), and Insights. The students were tested with both a 65-question short answer "Cognitive Abilities" test and 25-items from the Third International Math and Science Study test (TIMSS). They found no significant difference between the hands-on and textbook students on the TIMSS test, and they found a difference in only one of four investigative tasks in which hands-on students performed 11% better than text students. More recently, Durmus and Bayraktar (2010) identified the use of conceptual change textbooks as more effective in changing physics misconceptions of fourth graders, than traditional lecture instruction, but not more effective than hands-on laboratory instruction that included experiments. Silk, Schunn, and Cary (2009) found no significant difference in science reasoning gains made by middle school science students in textbook-based, inquiry-based and engineering design based classes.

Instructional reform efforts have expanded beyond the k-12 classroom movement initiated by *Project 2061* (Ebert-May, Brewer, & Allred, 1997; Udovic, Morris, Dickman, Postlethwait, & Wetherwax, 2002). In 2004, *Science Magazine* printed an article demanding new teaching methods in college level science classrooms. Handelsman et al. (2004) reported that, despite high enrollments in introductory science classes, engaging techniques can be, and should be used. They claimed that research universities needed to revamp their science courses to include scientific teaching. They further stated that administrators needed to provide training opportunities for faculty and encourage networking of best practices so that proven methods could be shared and adopted in other classrooms. They asserted the importance of this effort by suggesting a reward system for improved teaching techniques that is part of the tenure process.

The implementation of alternative curricula is labor intensive. A study on the implementation of a problem based learning (PBL) approach in a high school classroom highlighted the difficulties faced by teacher and students. The teacher struggled with changing her role in the classroom from a "teacher as leader" role to a facilitator. The teacher had to adopt new methods for interacting with students and trust assessment techniques that were new to her. Because students were unaccustomed to the new learning style, student engagement was a problem at first (Goodnough & Cashion, 2006). The teacher was able to make adjustments to her methods and successfully adopt the PBL approach with the guidance of two university researchers. It is important to note that this type of assistance is not readily available for the average science teacher, which raises questions about how successfully a program can overcome identified challenges without university-based resources.

Another concern for teachers considering alternative techniques is time. These approaches to learning are more time consuming than traditional methods. In a chapter on *Best Practices for Teaching Science: What Award Winning Classroom Teachers Do* Wawrzyniak (2007), a New Hampshire high school science and engineering teacher described this conflict between time and implementing hands-on science instruction.

> I was experiencing the same problem faced by many of my colleagues. Hands-on science is time-consuming. It is easier to cover the entire curriculum if the number of hands-on activities is limited in favor of whole-group demonstrations and lectures. Learning outcomes are generally better for educationally sound hands-on activities than for whole-group activities, but there is not enough time to use them to teach everything. (pp. 5-9)

The vastness of science content that needs to be covered overwhelms teachers and causes conflict between quality and quantity.

Given the lack of definitive research and the current pressure on teachers to increase student test scores, it seems reasonable that teachers may be reluctant to give up the textbook as a primary instructional tool. However, some studies show that using these techniques offer gains that do not show up on the typical standardized tests (Cofer, 1996; Kennell, 2000; MacIver, Young, & Washburn, 2001). For example, implementing web-based learning was shown to increase student motivation in a high school earth science course (Wang & Reeves, 2006). Similarly, in 2006, Yager et. al, reported findings from a study in which students who were in STS science classes experienced a significant increase in positive attitudes about science while students who were in textbook based classes experienced a decrease in attitude toward science, although no difference was found in their gains in science concepts. Teachers are left to wonder if these gains outweigh the risk of losing academic ground.

What seems to be missing in these studies is the amount of time students actually spend reading the text. References to textbook-based classrooms do not necessarily signify a class that spends an entire 50 minute class period reading the text. They refer to the curriculum that the teacher draws from. For example, a textbook-based class may still have labs that could be considered hands-on. The labs and activities used are those recommended by the textbook curriculum. The actual amount of time spent reading the text is not considered in the existing research, so it is unclear what role the text plays in student learning in these classes. Addressing that issue will help teachers make more informed choices about the implementation of alternative learning techniques which may increase student interest (Blumenfeld et al., 1991), improve student attitudes toward science (Ebenezer et al, 2006), and benefit students facing greater challenges (Haberman, 1991). This study gives a more detailed look into textbook use, specifically at the amount of time high school biology students spend reading the text and its influence on learning. The purpose of the analysis is to answer the question: Does the amount of time that students spend reading their high school biology text influence long term academic achievement?

Description of the Data

The following analysis uses data from project FICSS (Factors Influencing College Science Success). Students enrolled in their first semester of college biology, chemistry, and physics courses at 55 different 4-year colleges and universities in the fall semesters of 2002 and 2003 were surveyed about their high school biology experience. The sample included students from both public and private institutions from 31 different states.

The analysis for this study used a subset of the project FICSS data that included only students enrolled in introductory college biology. This subset was comprised of 1088 male and 1624 female students. The racial breakdown was 77 percent White, 8 percent Black, 6 percent Asian/Pacific Islanders, and 1 percent American Indian/Alaska Natives. Almost 5 percent of the respondents considered themselves to be multi-racial, and 7 percent of the respondents indicated that English was not their primary language. More than 32 percent of the students had at least one parent attend or complete graduate school, and close to 30 percent had at least one parent complete 4 years of college. Almost 24 percent had a parent attend some college, 10 percent had a parent finish high school, and only 2 percent did not have a parent who finished high school.

In an effort to determine if the amount of time *spent reading biology text* (TRT) is a good predictor for *biology grades*, our first analytical model involved running a multiple regression using (TRT) as our predictor variable and *biology grades* as our outcome variable while controlling for *Gender, English as a Primary Language* (EPL) and *Highest Parental Education* (HPE).

Table 1. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.058(a)	.003	.002	3.877	.003	1.992	4	2376	.093

a Predictors: (Constant), Highest Parent Education Level, Time Reading Text, Gender, English Primary Language

Predictor Variable: Time Spent Reading the Text

The college biology students in project FICSS were asked about their high school biology reading habits. Almost 12 percent of the students in this subset indicated that they did not read the textbook at all, and almost 24 percent indicated they spent an average of 10 minutes a day reading the text. 25 percent indicated they read for 20 minutes a day, and close to 23 percent indicated they read the text for 30 minutes a day. 7.6 percent indicated they read for 40 minutes per day, and more than 9 percent indicated they read for 50 minutes per day. The mean time spent reading the text was less than 22 minutes per day.

Outcome Variable: High School Biology Grades:

Respondents were asked to indicate the grade they earned in their high school biology courses. The possible grades were A, B, C, D, F. Each grade was assigned a point value and coded as F = 1, D = 2, C = 3, B = 4, and A = 5. The biology grade data distribution was somewhat negatively skewed with the majority of respondents (1516) indicating they earned an A. Almost 32 percent (783) earned a B; 6.5 percent (161) earned a C, less than one percent (14) earned a D, and none indicated they earned an F. Approximately 9 percent of the respondents left the question blank reducing the respondents to be included in the data (N=2474). The average grade was a 4.69 (B-A) with a standard deviation of 3.81. This distribution is not surprising considering the population of the study includes students who had been accepted into college and had enrolled in a college biology course.

The relationship between TRT and the ACT scores was explored for our second analysis. Teachers are in control of the tasks and activities within their own classroom that contribute to high school student grades. However, ACT scores are not under the control of the teacher and are a more consistent measurement across the population of students. Students were asked to indicate their scores for the science reasoning section of the ACT. Almost 1000 students did not indicate an ACT science reasoning score decreasing the sample size to N=1759. This large number may be due to ACT scores not being an admissions requirement for all colleges. Many students also opt to take the SAT instead. About 5% of the students indicated that they earned an ACT score less than 16. 71% earned between 17 and 28, and more than 23% earned 29 or higher.

Analysis

We conducted a multiple regression to test whether *Time Spent Reading Biology Text* (TRT), our predictor variable, was associated with *Biology grades*, our outcome variable, at the 0.05-level of significance after controlling for *Gender, English as a Primary Language* (EPL) *and Highest Parental Education* (HPE). Results in Table 2 show that TRT was not a significant predictor of Biology grades. Gender was the only significant predictor. To clarify, the mean grade of female students was significantly higher than the mean grade of male students by 0.335 while controlling for all the other variables in the model (t=2.030, $p<.05$). However, there was no significant relationship between the amount of time students spent on reading Biology texts and their Biology grades (t=-1.858, $p>.05$). We also investigated for correlations among the variables to determine if multicollinearity was likely to be a problem. All of the correlations were below 15% indicating a low risk for multicollinearity.

Table 2. Regression Table

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	SE B	B	t	Sig.
1	(Constant)	4.175	.452		9.233	.000
	Time Reading Text	-0.105	.057	-0.039*	-1.858	.063
	Gender	0.335	.165	0.042**	2.030	.042
	English Primary Language	0.296	.316	0.019	.936	.350
	Highest Parent Education Level	-0.020	.075	-0.006	-.273	.785

Note. R2 =.003. *$p<.10$, **$p<.05$. Dependent Variable: Biology Grade

Our second analysis investigated the correlation between TRT and ACT scores after controlling for Gender, EPL, and HPE. Analysis concluded there was no statistically significant correlation between the two, $r_{12.345} = .026$, $p>.05$. For interpreting $r_{12.345}$, 1 and 2 stand for TRT and ACT scores, while

3, 4 and 5 represent three control variables *Gender*, EPL and HPE respectively. In other words, after partialing out the three control variables, the estimated correlation between TRT and ACT scores is 0.026, which was not significant at the alpha level of 0.05. Therefore, we may conclude that the amount of time students spent on reading biology texts was not significantly associated with their ACT scores in science reasoning.

Table 3. Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.037(a)	.001	.001	3.879	.001	3.210	1	2379	.073
2	.058(b)	.003	.002	3.877	.002	1.585	3	2376	.191

a Predictors: (Constant), Gender

b Predictors: (Constant), Gender, English Primary Language, Highest Parent Education Level, Time Reading Text

Discussion and Conclusion

The amount of time students spend reading their science textbook was not a good predictor for high school biology grades for the population surveyed in this study. Nor was there a significant relationship between the amount of time spent reading biology text and science ACT scores. This raises concerns about the effectiveness of improving academic performance and test scores through teaching methods relying on textbooks. As a result, teachers who decide to eschew a textbook-dependent curriculum are not likely to have an adverse effect on their students' high school grades in biology.

A study at the University of Oregon supports this argument. Researchers followed a college level introductory workshop-biology course for non-science majors for three years and compared student progress to those students in the existing traditional lecture and textbook based course. Students from the workshop-based course made reference to new views and attitudes about biology, while no students in the comparison course made such comments (Udovic et al, 2002). Other studies report improved student-teacher relationships with the use of non-traditional methods (Martin, 2006; Syh-Jong, 2007). Some efforts to include service learning have reported to influence career choices (Gustein, Smith, & Manahan, 2006; Kennell, 2000).

Because the use of textbooks does not seem to be related to knowledge gains beyond those offered through alternative methods, and existing studies show that alternative techniques in the classroom offer benefits beyond academics, it seems that expanding the use of alternative methods could be beneficial. It is reasonable to expect that this finding may apply to other content areas, and not just the science classroom, but research that is specific to those areas of study should be conducted in order to investigate the possible impacts.

Limitations

The use of textbooks may have potential benefits that were not measured in this study. It should also be noted that the population sampled for this study was that of students who were already enrolled in college and may be considered high academic achievers. A general population of high school students may have produced different results. When students left out data that was relevant to the analysis, they were dropped from the analysis. This could have created a response bias. In addition, the data is based on student self-report, which raises some concern about self-report bias. Students may have over-reported the amount of time they spent reading the text, or the grades or ACT scores they earned. Measures were taken to contextualize the environment by conducting the survey in science classes in order to help lessen self-report bias.

The data in this study does not take into account the experience level of the teachers, nor does it take into account the quality of the texts. It is also important to consider the idea that using alternative classroom techniques is not exclusive of the textbook. It is likely that a combination of the alternatives and the use of the textbook were experienced by most students in this study. Furthermore, students who indicated they did not read the text at all may in fact have experienced a class in which the text was not used or they could be in a textbook-based class but chose not to read the book. Each of these scenarios would most likely have different effects on a student's grade. Therefore the reported amount of time students spent reading the text does not tell us the degree to which they experienced the alternative classroom methods. It can be said that for the population in this sample, spending more time reading the textbook is not related to academic achievement. This is one piece of the puzzle and administrators and educators will need to further analyze their own practices and students as well as other evidence to make informed choices about policy and curriculum.

Future research could focus on including more information about the classroom techniques used (both text-based and alternative) in relation to students' long-term gains. In addition, expanding this research to science classes other than biology could offer a broader picture on the use of texts in the classroom. It is also important to consider the methods used in content areas other than science to determine the efficacy of various techniques across academic areas.

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