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Evaluation of Elementary Students' Attitudes Toward Science as a Result of the Introduction of an Enriched Science Curriculum[1]

One of the challenges facing school educators is motivating students to learn science. This study is part of an evaluation of enriched science curriculum introduced in five western Canadian (Alberta) urban schools. The objective was to develop a multidimensional instrument suitable for evaluating the attitudes of students toward science with a potential to be used for classroom assessments. The study addressed instrument validity and reliability by testing a 40-item questionnaire using data from grade 4 students. The six-factor solution provided a conceptual foundation for future studies and instrument refinement. Overall, students who had been learning the experimental curriculum for three years displayed more positive attitudes toward science than control students.

Un des défis auquel font face les enseignants est celui de motiver chez les élèves le désir d'étudier les sciences. Cette étude fait partie d'une évaluation du programme enrichi de sciences qui a été présenté dans cinq écoles canadiennes (albertaines) en milieu urbain. Cette étude vise à développer un outil multidimensionnel propice à l'évaluation des attitudes des élèves face aux sciences. L'outil pourrait éventuellement servir dans les évaluations en salle de classe. La validité et la fiabilité de l'outil ont été étudiées en faisant passer un questionnaire de 40 questions à des élèves en quatrième année. La solution à six variables a fourni un fondement conceptuel pour des études ultérieures et l'amélioration de l'outil. Sur l'ensemble, les élèves qui suivaient le programme expérimental depuis trois ans ont démontré des attitudes plus positives face aux sciences que les élèves du groupe contrôle.

Introduction

Success in the new global economy and expansion of knowledge-based careers depends on how well young people are educated in scientific and technical disciplines (US Department of Education: The National Commission on Mathematics and Science, 2000). In Canada a 2001 study demonstrated that only a small proportion of Canadian students going into the elementary school system pursue a career in science and technology. Many students find mathematics and science "difficult" and "boring" and opt for not taking these subjects in high school. "Even when they have done well in mathematics and

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science in the past and believe that the subjects are important to them if they want to succeed in life, many students are unwilling to pursue them" (Bordt, de Broucker, Read, Harris, & Zhang, 2001, p. 9).

Research in science education (Osborne, Simon, & Collins, 2003; Pell & Jarvis, 2001; Ramsden, 1998) call attention to the persisting problem of the alienation of young people from science and stress the importance of continuing inquiries into students' attitudes toward science to understand and remedy the problem. Based on Fishbein and Ajzen's (1975) general conceptual definition of attitudes as the amount of affect for or against some object, and capitalizing on Cheung's (1988) specific definition of attitudes toward mathematics, this study refers to science attitudes as *affective evaluation of situations in which science is learned as well as views of science as a subject*. "Children with positive attitudes are more likely to sustain learning and to want to pursue subjects they enjoy" (Pell & Jarvis, 2001, p. 849). There is evidence of a positive relationship between attitudes toward science and student achievement for all levels of student performance and for both sexes (Germann, 1988; Oliver & Simpson, 1988; Schibeci & Riley, 1986; Weinburgh, 1995). Positive attitudes, however, could be a stronger stimulus for students' commitment to science after completing school because high academic achievement by itself is not a guarantee that a student would choose a science-related career. Attitudes toward science may influence the propensity for pursuing science-related professions even in young students. Blatchford (1992), for example, found that "at 11 years there appears to be a concern with future career and an awareness of the importance of school work in that career" (p. 110). So students' preferences for future careers may start taking shape as early as elementary school. Attitudes are learned (Fishbein & Ajzen; Koballa, 1988) and hence can be affected by stimulating students' positive experiences with learning science.

Research indicates that enthusiasm for science is relatively high among primary school students, but tends to decline with grade level starting toward the end of the primary grades and continuing into secondary school (Bordt et al., 2001; Osborne et al., 2003; Pell & Jarvis, 2001; Piburn & Baker, 1993; Weinburgh, 2000). Furthermore, Kanai and Norman (1997) found that both male and female school students as they grew older tended to lose their desire to pursue science and mathematics in college. The variables affecting students' attitudes toward science should be examined in order to identify means of enhancing students' interest and aspirations to pursue scientific inquiry. The following variables might (negatively) affect students' attitudes toward science (Pell & Jarvis; Piburn & Baker; Ramsden, 1998; Reiss, 2004; Weinburgh).

- inadequate instructional strategies employed in the classroom such as lack of inquiry-based, hands-on methods in teaching science and students having not much control over their own learning (e.g., lack of cooperative learning);
- uninteresting or unchallenging science lessons;
- students lacking awareness of the links between science and society and real-life applications of science; and
- lack of adequate training and competence in teaching science (i.e., quality of teaching).

In addition to the mentioned variables, a student's sex has been identified as a significant factor that may explain attitudes toward science. Although studies such as Fleming and Malone (1983), Simpson and Oliver (1990), and Wareing (1990, cited in Germann, 1994) indicated little or no relationship between sex and students' attitudes toward science, some studies found boys to be more positive than girls on dimensions such as excitement, enthusiasm, and enjoyment (Neathery, 1997; Pell & Jarvis, 2001; Weinburgh, 2000). Boys also were found to reveal more confidence than girls in their science abilities (Kanai & Norman, 1997).

Murphy (1997) and Osborne et al. (2003) cited a number of studies attributing gender differences in performance and attitudes toward science to varying cultural socialization patterns including perceived roles and expectations. Women have fewer opportunities to use technological and measurement devices or to observe scientific phenomena. Lack of experience in and understanding of science contributes to negative attitudes to science. Furthermore, there is evidence suggesting that the gender gap in attitudes toward science may increase with age (Murphy). Specifically, Pell and Jarvis' (2001) study found no significant gender-based variations in younger students' attitudes (ages 5-10), but revealed that 11-year-old girls were significantly less enthusiastic about science than boys. Therefore, in order to understand better the effects of strategies for positively influencing students' attitudes toward science and to use the opportunities for encouraging students to study science, it is important to document classroom practices systematically and measure their outcomes beginning with the early grades.

An assortment of instruments has been developed to evaluate students' attitudes toward science including a well-used, comprehensive TOSRA test (Fraser, 1981) and the Scientific Attitude Inventory (SAI) (Moore & Foy, 1997). The Council of Ministers of Education, Canada [CMEC], 1999) issued a comprehensive Science Assessment Student Questionnaire encompassing a variety of school-related and socioeconomic student indicators including students' attitudes toward science as well as science-related learning environments. In addition, a number of other studies present various science attitude scales and items (Germann, 1988; Gogolin & Swartz, 1992; International Study Center, Boston College, 1995; Nyberg & Clarke, 1982; Parkinson, Hendley, Tanner, & Stables, 1998; Pell & Jarvis, 2001; Schibeci & Riley, 1986; Wareing, 1982; Ye, Wells, Talkmitt, & Ren, 1998; Yore, Shymansky, & Anderson, 2001).

The instruments vary substantially in their purpose and conceptual makeup. Some are comprehensive, reflecting a multidimensional nature of attitudes toward science and containing a large number of items (e.g., TOSRA); some intend to measure a general attitude toward science in school with a limited number of items (Germann, 1988); and some offer a "generic," cross-subject approach to assessing students' attitudes (Nyberg & Clarke, 1982). Whereas SAI reflects both beliefs about and affect toward science and related matters, other scales (e.g., TOSRA) put emphasis on students' affect (e.g., students enjoying or disliking science, science experiments, science lessons, etc.). Most of the mentioned instruments were tested on students in junior and senior-high age brackets or older (college students), and only a few studies incorporated samples of elementary school students. In general, little attitudinal research with young elementary school students has been reported (Pell & Jarvis, 2001), including creating and testing appropriate attitude measurement instruments.

Despite the range of existing instruments, the present project required a customized approach to measuring students' attitudes toward science generally, but also specifically in relationship to project parameters (see the section below on the context of the study). First, the instrument needed to be comprehensive enough to make it possible for evaluators to assess various dimensions of students' attitudes toward science, yet be concise item-wise. Specifically, the questionnaire should be easy to use and not time-consuming for teachers and not tiresome for students (especially if evaluators wished to include supplementary, "non-attitude" items in the instrument). Second, the questionnaire should be adjusted to the level of elementary school students to allow attitude comparisons at various stages of schooling. Third, the instrument needed to be reflective of the science curriculum and associated curriculum-based activities. Therefore, the purpose of the current study was twofold: (a) to develop and test a succinct yet comprehensive instrument suitable for measuring attitudes toward science in both young and older school students; and (b) to explore the relationship between introduction of an enriched science learning environment and students' attitudes toward science.

Context of the Study

A project called Scientists 2010 was launched in 1999 in a large western Canadian (Alberta) city with the key purpose of exploring various avenues of creating learning environments and experiences that would contribute to: (a) students making sense of science; (b) feeling positive about science; and (c) getting inspired to pursue studies and careers in science and technology. Five schools with relatively stable student populations (low transience) in low-middle to middle-class city neighborhoods have been participating in the project starting with the 1999-2000 school year when the targeted population of students was in grade 2. The project was conceived as a long-term initiative and was intended to continue with this cohort of students to grade 12 in 2010.

Because outside factors such as family and community can be influential in shaping students' attitudes toward learning in general and science in particular, the project was conceived at a scale broader than just school science and direct teacher influences. The purpose of the Scientists 2010 program is to provide opportunities for learning through the integration of hands-on learning experiences, science inquiry, and problem-solving through technology in the existing curriculum by developing creative partnering between the schools, industry, parents, and the general community. Partnering with organizations like science museums is considered a useful strategy to better engage students in the subject matter (Brown et al., 2005). A large city scientific and educational center and museum, the Odyssium (currently the TELUS World of Science) has been the central partner in the project. The enriched learning environments provided to the Scientists 2010 students and particulars of their implementation are addressed and evaluated in the final report resulting from a qualitative inquiry into the project (Rowell, Nocente, Geelan, McClay, & Oberg, 2002). This article is limited to the following brief account of the project features based on the report.

- *Integrated learning opportunities at school*. The project aimed at both *curricular integration* (i.e., integration of learning about science with learning about technology and with other areas of the curriculum) and *technological integration* (i.e., integration of information and communication technologies into student learning with a focus on science).
- *Greater access to computers and the Internet*. Each classroom had 15-20 computers connected to the Internet, which was used by the students for research projects, to supplement a class activity, or to expand on a concept.
- *Museum School Weeks at the science center (Odyssium) and other field trips*. A week-long Museum School intended to provide field experiences to stimulate students' enthusiasm for learning. For example, in grade 4, congruent with the science curriculum, the Museum School unit was Building Devices and Vehicles that Move. In addition, students attended presentations and IMAX movies related to the school science program and toured museum galleries. Finally, project students had an opportunity to go on an out-of-city dinosaur dig field trip to the Dinosaur Provincial Park in Drumheller (Alberta).
- *E-mentoring of students by volunteers from the community*. The e-mentoring component of Scientists 2010 aimed at developing students' skills in technology use; writing skills; improving the understanding of science and technology; providing guidance on the importance of education; developing a student-mentor relationship; and providing the community with an opportunity to support the project and the education system. Due to the difficulties of recruiting all mentors from the fields of science and technology, the e-mentors were recruited from a broader pool of volunteers. Students sent science-related messages to e-mentors about once per week during class time using a secure software program.
- *Support and encouragement in school, home, and community*. In addition to the enriched learning opportunities in and outside their schools, the project offered other avenues for parental and community involvement in the teaching and learning such as providing family membership to the science center and industry-classroom linkages (e.g., arranging for guest speakers for science units). The latter opportunity, however, received limited development at the time this study was conducted.

Scope and Utility of the Study

The research reported here is a result of the first phase of evaluating the implementation of the project in the 2001-2002 school year when the Scientists 2010 students in the five project schools described above were in grade 4. The recurring measurements of attitudes through time would make it possible to trace the effects of the experimental instructional strategies from the early grades when students' attitudes to science tend to be most positive, to junior high and high school when these attitudes tend to become less positive.

The focus of the research reported here is the design, testing, and use of a questionnaire to measure students' attitudes toward science. Evaluating attitudes is important for documenting the dynamics of students' disposition toward science. In addition, this study explores gender differences in students' attitudes toward science and compares preferred learning styles of the project and mainstream (control) students. The goal was to address the following questions.

- Are there any differences in science attitudes between the project and control students (after three years of the project implementation)?
- Are there any gender-related differences in students' attitudes toward science both within the project and control groups of students and between these groups?
- Are there any differences in the preferred learning styles between the project and control students?

Method

Questionnaire Design

A survey instrument was developed through a series of face validity analyses with curriculum and science consultants and with a team of university science education scholars. As a result, wording used in the questionnaire was adjusted to be meaningful to grade 4 students, and steps were taken to ensure that relevant concepts were addressed. While recognizing the value of considering preceding research on related instruments, this study attempted to be informed by earlier research, but at the same time maintain a balance between being grounded in existing knowledge and developing certain concepts and items independently. Because science attitude is a complex, multifaceted concept (Fraser, 1981; Gogolin & Swartz, 1992; Ramsden, 1998), the questionnaire was conceived as a *multidimensional* instrument for measuring various aspects of attitudes toward science. Some constructs built into the instrument reflect the attributes of attitudes that have been already identified and explored in earlier studies. For example, congruent with related research and assessment of student attitudes toward science involving various age groups (Gogolin & Swartz; Parkinson et al., 1998; Pell & Jarvis, 2001; Schibeci & Riley, 1986; Yore et al., 2001), the instrument focused on the affective and emotional domains such as liking science versus perceiving it as a boring and difficult subject; perceived usefulness and importance of science; and students' confidence that they can succeed in learning science. The items used to measure these concepts were partly based on the existing literature, with some of them modified, in particular to adapt them to elementary student respondents and make them more personalized. For example, the item "Science is helpful in understanding today's world" (Gogolin & Swartz) is similar to a personalized item from the Scientists 2010 questionnaire "Science helps me understand the world around me."

In addition to the mentioned constructs, a dimension was developed to measure students' response to cooperative learning in the science class and appreciation of hands-on or real-life applied science curriculum components such as school field trips and visits to the science center—the activity that has been one of the major features of the enriched science curriculum in the project schools.

The dimension measuring perception of the usefulness of science was supplemented with a set of cognitive (non-affective) items scanning students' awareness of school-based science topics and activities. The related grade 4 curriculum topics were as follows: Waste and Our World; Wheels and Levers; Building Devices and Vehicles that Move; Light and Shadows; and Plant

Growth and Changes (Alberta Learning, 1996). In constructing and evaluating the conceptual dimensions, 40 corresponding items were randomly distributed in the final version of the questionnaire given to the students. Other supplementary sections of the questionnaire comprised students' preferred learning styles; attitudes toward going to school and using computers; and questions about engaging in various science-related activities outside school such as reading about science, watching science-related programs on TV or video, and family visits to science centers, museums, and botanical gardens.

A 5-point Likert-type scale was used to measure students' attitudes toward science. The answer choices were: *Strongly agree, Agree a little, Disagree a little, Strongly disagree*, and *I'm not sure*. The scores on the questionnaire items were coded so that lower scores uniformly reflect more negative attitudes (minimum=1) and higher scores reflect more positive attitudes (maximum=5). The *I'm not sure* answer choice was assigned a middle position, in between the pairs of positive and negative answer categories (coded as 3).

After completing the initial design, we pilot-tested the questionnaire with a class of 25 grade 4 students in a non-project school. Item correlations with the total score were reviewed as a basis for further refinement of the instrument, and some items were rephrased based on the pilot students' responses. A copy of the questionnaire is included in the Appendix.

Survey Administration

Five project (Scientists 2010) schools, which have low-transient student populations and are located in typical low-middle to middle-class areas of the city, cooperated in the study. These schools had been participating in the project for three years. Five control schools comparable in terms of socioeconomic contexts to the project schools were selected by the project science consultants. The questionnaire was administered in late May to mid-June 2002. All students in grade 4 classes in both project and control schools were asked to complete the questionnaire.

One hundred, ten questionnaires were distributed to the project students during class time. Students had the option of not completing the questionnaire at their discretion. Eighty-five students completed questionnaires for a 77% return rate. The response rate from the control schools was 110/129 for an 85% return rate. There were 41 male and 43 female respondents in the project group (one respondent did not identify his or her sex) and 59 male and 51 female respondents in the control group.

Results

Construct Validity of the Instrument

Explorative factor analysis through SPSS Factor Analysis (principal components extraction with promax rotation and pairwise deletion) was run on the attitude items using a composite sample of both project and control students (195 respondents).[2] The purpose of this exercise was threefold. First, factor analysis would reveal patterns of correlations among the variables and hence underlying latent dimensions in students' attitudes. This would make it possible to test and perfect the original instrument (e.g., determine whether the psychological constructs built into the instrument stood out in the factor analysis and which questionnaire items were the best fit in the model). Second,

Table 1
Attitudes Toward Science—Six-Factor Solution

Items	*Factors*	*Factor Loadings**
Factor 1: Appreciation of Science (Cronbach's alpha=0.83)		
Q26	I think scientists have interesting jobs	0.840
Q32	I would like to be a scientist	0.762
Q55	Science is one of my favorite subjects	0.618
Q45	Science is fun	0.591
Q27	Science makes me think	0.557
Q52	I enjoy learning science	0.534
Q41	Science is not very important outside of school	0.531
Q47	Going on science field trips helps me better understand how nature works	0.465
Factor 2: Appreciation of the Science Center/Odyssium (Cronbach's alpha = 0.88)		
Q53	Visiting the Odyssium helps me understand science	0.882
Q38	I discover a lot of new things during our visits to the Odyssium	0.860
Q20	I like visiting the Odyssium with my class	0.840
Q29	Visiting the Odyssium makes me like science more	0.794
Factor 3: Practical Application of Science (Cronbach's alpha = 0.73)		
Q49	In science we answer questions by doing experiments	0.682
Q36	In science we ask questions about the world	0.656
Q40	In my science class we ask questions about how different plants grow	0.591
Q28	In science we learn how to help nature	0.571
Q17	In my science class we do many different activities	0.543
Q42	In science we learn how to make machines we need	0.523
Q44	Science helps me understand the world around me	0.427
Factor 4: Confidence in Learning Science (Cronbach's alpha = 0.74)		
Q39	I usually do well in science	0.754
Q48	I am as good at science as most other students	0.701
Q37	Science is harder for me than for other students	0.670
Q21	I don't do well in science	0.629
Q51	It is hard for me to work on science with other students	0.534
Factor 5: Attitudes Toward Cooperative Learning (Cronbach's alpha = 0.76)		
Q56	I learn the most when I work with other students	0.877
Q46	I like to work on science with other students	0.757
Q18	Working together helps everyone on a science project	0.678
Q35	I like to help other students in my science class	0.516
Factor 6: Difficulty of Science (Cronbach's alpha = 0.51)		
Q22	We have to do too much home work in science	0.793
Q30	We do too much science at school	0.604
Q19	Science is difficult	0.521
Total science attitude scale—Cronbach's alpha=0.90		

*Only items with loadings greater than 0.40 are included.

factor analysis could result in new insights into the data structure. Third, reducing a large number of questionnaire items to a few factors would provide a base for further data analyses.[3]

Table 2
Factor-Based Differences in Attitudes Toward Science Between Project and Control Groups of Students (Factor-Generated Subscales)

	Project Students			Control Students		
Factor-based Subscales:	*Mean*	*N*	*SD*	*Mean*	*N*	*SD*
1. Appreciation of science	4.26*	75	0.77	4.00*	100	0.89
2. Appreciation of science center	4.73**	80	0.65	4.01**	107	1.04
3. Practical application of science	4.35	78	0.62	4.16	104	0.76
4. Confidence in learning science	3.96	81	0.98	3.81	103	0.98
5. Attitudes toward cooperative learning	4.24	82	0.98	4.21	105	0.81
6. Difficulty of science	3.82	80	0.90	3.83	103	1.07

*$p<0.05$; **$p<0.01$ (Mann-Whitney test, one-tailed).

The Six-Factor Model

Six factors with eigenvalues over 1 were identified as a result of factor analysis (Table 1).[4] Factor loadings in the table are correlations between a factor and an item (variable). The magnitude of the loadings (maximum absolute value of 1) reflects the importance of items to a factor. In this study only factor loadings with an absolute value of 0.40 or higher were interpreted. Cronbach's alpha (reliability) coefficients shown in the table are estimates of internal consistency of each of the factor-based subscales or an estimate of how well a set of items measures a single latent construct. The alpha coefficients are interpreted in the range from 0 to 1, and the higher values indicate the higher scale reliability.

Three factor-based dimensions or subscales—Appreciation of the Science Center (Factor 2), Confidence in Learning Science (Factor 4), and Attitudes toward Cooperative Learning (Factor 5)—almost completely mirror the original conceptual dimensions. Factor 1 (Appreciation of Science) combines logically allied concepts of liking science and perceived importance of science. Cognitive (non-affective) items loaded mostly on Factor 3, which conveys the notion of Practical Application of Science. Finally, the items related to the perceived difficulty of science loaded on a separate factor (Difficulty of Science, Factor 6). All subscale Cronbach's alpha coefficients were at or well above the 0.70 criteria (Nunnally & Bernstein, 1994), indicating good internal consistency, with the exception of the last, Difficulty of Science, subscale (0.51). There was evidence of both discriminant and convergent validity, which are the two subcategories of construct validity. Moderate subscale intercorrelations, typically not exceeding 0.45 (Spearman's rho correlations), provide evidence for discriminant validity (i.e., suggest that the six factor-based dimensions, although related to each other, are conceptually distinct). Reasonably high item loadings on each of the factors (Table 1) point to the relationship of the items to the common latent construct and confirm convergent validity. In summary, the six-factor solution is logical and interpretable, reflects reasonably well the original conceptual dimensions built in the instrument, and offers additional insights into the data.

Table 3
Item-Based Differences in Attitudes Toward Science

Items (statistically significant differences only):	*Project Students*			*Control Students*		
	Mean	*N*	*SD*	*Mean*	*N*	*SD*
17. In my science class we do many different activities	4.84**	85	0.57	4.61**	110	0.81
20. I like visiting the Odyssium with my class	4.76**	85	0.83	4.04**	110	1.20
29. Visiting the Odyssium makes me like science more	4.62**	84	0.88	4.09**	109	1.22
38. I discover a lot of new things during our visits to the Odyssium	4.80**	84	0.66	3.87**	107	1.33
53. Visiting the Odyssium helps me understand science	4.79**	82	0.60	4.06**	108	1.24
28. In science we learn how to help nature	4.45*	85	1.04	4.17*	107	1.23
32. I would like to be a scientist	3.53*	83	1.53	2.99*	106	1.68
40. In my science class we ask questions about how different plants grow	4.79**	84	0.64	4.36**	109	1.18
45. Science is fun	4.45*	85	1.14	4.17*	109	1.27
49. In science we answer questions by doing experiments	4.49*	83	1.01	4.25*	109	1.06
55. Science is one of my favorite subjects	4.12*	83	1.30	3.54*	109	1.64

*$p<0.05$; **$p<0.01$ (Mann-Whitney test, one-tailed).

Comparison of Project and Control Students' Attitudes Toward Science

The six-factor solution was examined further in order to compare the differences in students' attitudes by dimension. Mean scores were calculated for each of the six factor-based dimensions or subscales by summing item raw score points and dividing the sum by the number of items in the factor so that higher scores uniformly indicate a more positive attitude on a factor. The differences between means in skewed distributions were tested using the Mann-Whitney test.

The evidence from Table 2 is that consistently with the above-cited findings, young (grade 4) students in both project and control schools were overall positively attuned toward science or learning science (maximum score=5). Still, project students, who received enriched science curriculum, were more positive than their control counterparts. Specifically, project students scored significantly higher than control students on subscales such as Appreciation of Science and, not surprisingly, on Appreciation of the Science Center. Visiting the city science center was one of the key features of the enriched curriculum in the project schools. The results suggest that intensified, hands-on use of a science center or museum may have a positive effect on students' attitudes toward science (see also the results on individual questionnaire items in Table 3).

Table 4
Differences in Attitudes Toward Science Between Control Males and Control Females

	Control Males			Control Females		
Statistically significant differences only:	*Mean*	*N*	*SD*	*Mean*	*N*	*SD*
Factor-based subscales:						
Practical application of science	4.29*	56	0.75	4.01*	48	0.76
Items:						
21. I don't do well in science.	4.10**	58	1.28	3.31**	51	1.62
42. In science we learn how to make machines we need.	4.05**	57	1.46	3.25**	51	1.65

*p<0.05; **p<0.01 (Mann-Whitney test, two-tailed).

In addition, scale-based data in Table 2 indicate that although both project and control students were generally appreciative of science and cooperative learning of science, their confidence in being successful in learning science was somewhat less pronounced. These results may be explained by relatively low scores on the Difficulty of Science subscale. Experiencing difficulties in learning science may be related to confidence issues. The finding that students may perceive science as interesting or practical, but not as easy is corroborated by the results of other studies involving older students (Osborne et al., 2003).

Item-based mean differences were statistically significant for 11, or about a third, of the original questionnaire items (Table 3), with project students scoring consistently higher on the attitude scale than control students. Specifically, project students gave a higher rating than their control counterparts to the items conveying enjoyment with learning science ("Science is fun" and "Science is one of my favorite subjects"). Project students also scored higher than control students on the item reflecting the inclination to become a scientist in future ("I would like to be a scientist").

Gender Differences in Students' Attitudes Toward Science

There were no statistically significant differences in attitudes toward science between project male and female students (based both on generalized mean attitude subscale scores and on individual item-based mean scores). In the control group, however, girls scored somewhat lower than boys on the Practical Application of Science subscale (Table 4). With regard to the item-based differences, control girls scored significantly lower than control boys on two items including a confidence item "I don't do well in science" and a cognitive item "In science we learn how to make machines we need."

Analysis of mean score differences between project and control boys and project and control girls resulted in a variety of statistically valid differences. The generalized, dimension-based analysis revealed that not surprisingly, both project boys and girls were more appreciative of the science center than their control counterparts (Table 5). In addition, project girls scored higher than control girls on the Appreciation of Science and Practical Application of Science subscales.

Table 5
Differences in Attitudes Toward Science Between Project and Control Males and Project and Control Females (Factor-Generated Subscales)

	Project Males			*Control Males*		
Factor-based Subscales:	*Mean*	*N*	*SD*	*Mean*	*N*	*SD*
1. Appreciation of science	4.30	36	0.75	4.05	54	0.96
2. Appreciation of the science center	4.73**	38	0.71	4.07**	57	1.04
3. Practical application of science	4.37	38	0.64	4.29	56	0.75
4. Confidence in learning science	4.04	40	1.04	3.88	56	0.93
5. Attitudes toward cooperative learning	4.19	40	1.06	4.19	56	0.87
6. Difficulty of science	3.96	38	0.86	3.78	57	1.14
Factor-based Subscales:	*Project Females*			*Control Females*		
1. Appreciation of science	4.22*	38	0.80	3.95*	46	0.82
2. Appreciation of the science centre	4.80**	41	0.39	3.95**	50	1.05
3. Practical application of science	4.32*	39	0.62	4.01*	48	0.76
4. Confidence in learning science	3.87	40	0.92	3.73	47	1.04
5. Attitudes toward cooperative learning	4.37	41	0.81	4.23	49	0.75
6. Difficulty of science	3.69	41	0.93	3.89	46	0.99

*$p<0.05$; **$p<0.01$ (Mann-Whitney test, one-tailed).

More detailed, item-based analysis uncovered further patterns in the data (Table 6). In particular, project boys were more positive than control boys in their perception of difficulty of school science (item "We do too much science in school"). Project girls showed more enthusiasm for learning science than control girls (items "Science is one of my favorite subjects" and "Science is fun"). In tune with the introduction of an enhanced science curriculum in their schools, both project boys and girls agreed more than their counterparts from control schools that they did a variety of activities in their science class.

Preferred Learning Styles

The questionnaire asked respondents a question about preferred learning styles in science. As shown on Figure 1, project and control students revealed similar patterns of preferred learning styles. In general, the highest proportions of students from both groups preferred to engage in some form of cooperative or interactive learning. For example, the vast majority of students in both groups (three quarters or more) were inclined to work in cooperation with their classmates. Also, they liked working with the teacher (over 60% of students in both project and control group) and with help from their parents (over 50% of students in each group). At the same time, lower proportions of students in both project and control group (36.5% and 46.3% respectively) expressed a desire to work on their own in class, and even smaller percentages were inclined to work on their own at home. Despite the noted similarities, project students tended to be somewhat more prone to cooperative learning (namely, to work with a partner or with help from parents) than control students,

Table 6
Item-based Differences in Attitudes Toward Science Between Project and Control Males and Project and Control Females

Items (statistically significant differences only):	*Project Males*			*Control Males*		
	Mean	*N*	*SD*	*Mean*	*N*	*SD*
17. In my science class we do many different activities	4.80*	41	0.60	4.58*	59	0.88
20. I like visiting the Odyssium with my class	4.68**	41	0.99	4.15**	59	1.11
29. Visiting the Odyssium makes me like science more	4.61*	41	1.00	4.10*	58	1.25
30. We do too much science at school	4.08*	40	1.25	3.41*	59	1.66
38. I discover a lot of new things during our visits to the Odyssium	4.83**	41	0.59	3.91**	57	1.34
40. In my science class we ask questions about how different plants grow	4.80*	41	0.72	4.43*	58	1.06
53. Visiting the Odyssium helps me understand science	4.87**	38	0.53	4.09**	58	1.22
Items:	*Project Females*			*Control Females*		
17. In my science class we do many different activities	4.86*	43	0.56	4.65*	51	0.74
20. I like visiting the Odyssium with my class	4.93**	43	0.26	3.90**	51	1.29
28. In science we learn how to help nature	4.51*	43	1.03	4.02*	49	1.32
29. Visiting the Odyssium makes me like science more	4.69**	42	0.64	4.08**	51	1.20
38. I discover a lot of new things during our visits to the Odyssium	4.83**	42	0.58	3.82**	50	1.34
45. Science is fun.	4.40*	43	1.20	4.06*	51	1.24
49. In science we answer questions by doing experiments	4.48*	42	0.99	4.06*	51	1.21
53. Visiting the Odyssium helps me understand science	4.79**	43	0.51	4.02**	50	1.27
55. Science is one of my favorite subjects	4.00*	42	1.33	3.22*	50	1.69

*$p<0.05$; **$p<0.01$ (Mann-Whitney test, one-tailed).

whereas the latter, on the contrary, were more willing to work on their own (in class or at home).

Although none of the above-mentioned patterns in students' learning styles data were statistically significant, there were significant gender-based differences. Both project and control girls were less enthusiastic about working on their own in the science class compared with boys in the respective groups (project group: girls 23.3% [N=43], boys 48.8% [N=41], Chi-square=5.96, df=1, $p<0.05$; control group: girls 30.6% [N=49], boys 59.3% [N=59], Chi-square=8.87, df=1,

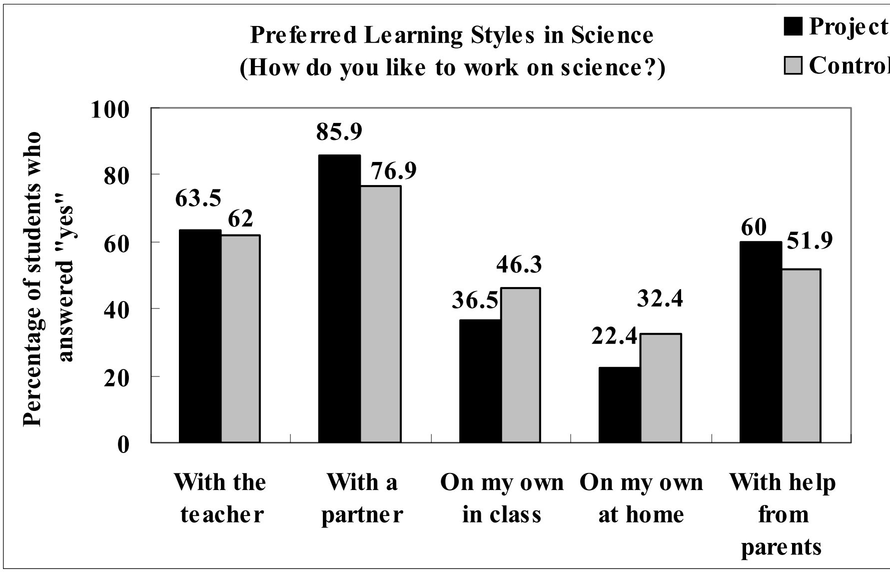

Figure 1.

$p<0.01$). At the same time, as many as 93% of project girls liked working with a partner compared with 75.5% of control girls (*N* project=43, *N* control=49, Chi-square=5.15; $df=1$; $p<0.05$).

Discussion and Conclusions

Factor analysis of attitude scale items resulted in logically consistent constructs, which both reflected the original conceptual structure and provided new insights into the latent dimensions underlying students' attitudes toward science. Cognitive items reflecting students' awareness about science routines and uses do fit logically in the factor structure. Although being built using curriculum-specific items, the final item set of the Practical Application of Science subscale is sufficiently general and therefore can be used (with some modifications, if necessary) on other student populations (e.g., various age groups with varied curricular engagements). Therefore, the six-factor solution is recommended for further use to assess students' attitudes toward science.

Differences in attitudes toward science and learning science between the project students (who received the enriched science curriculum) and control students (a comparison group who were not subject to the mentioned interventions) were in the hypothesized direction. Although as expected grade 4 students in both project and control schools were generally positively attuned toward science, statistically significant differences in mean scores consistently indicated more positive attitudes among the students from the project schools compared with their counterparts from the control schools.

As far as gender differences are concerned, there was some evidence of control girls being somewhat less confident in their abilities to do well in science than control boys, as well as showing less awareness in the practical applications of science. There were no significant gender-based differences in attitudes toward science in the project group of students. Refocusing analyses on the differences between project and control boys and project and control gilrs revealed more positive attitudes toward various aspects of (learning) science among both project boys and girls compared with the male and female respondents from the control schools. These gender-specific results complement general evidence in support of the hypothesis that introducing the enriched science curriculum may have a positive effect on students' attitudes toward science by illustrating that positive differences occur for both project boys and girls. This makes it possible to hypothesize further that it may well be that intervention projects at an early age (when gender differences in attitudes toward learning science are not yet pronounced) could help ameliorate gender variations in future, including contributing to more female students developing appreciation of and desire for learning science.

Complementary analysis of learning styles preferred by the respondents indicated that significantly higher proportions of project girls compared with control girls liked to learn cooperatively (team up with a partner) in a science class. Developing inclination and abilities for team work should encourage students' active engagement in learning as well as eliminate possible alienation of female students from the process of learning science.

This study demonstrates how research ideas and methodologies can be directly implemented in schools to benefit students. It offers educators a usable tool to capture and evaluate students' perceptions of school science as well as monitor changes as a result of curriculum interventions. The instrument measuring attitudes toward science is not limited to specific age groups and was tested with grade 4 students to make it appropriate for the younger student population. Consequently, programming and planning can be adapted to students to optimize their motivation to study science. In addition, the study contributes to the accumulation of evidence about specific schools' experiences in providing students with enriched opportunities to learn science based on the existing curriculum and outcomes associated with these efforts.

Further Research

We encourage others to adopt the six-factor attitude questionnaire (see the refined version in Table 1) for use in other studies of students' attitudes toward science and to report analyses of the questionnaire construct validity. It is recommended that the sixth dimension that emerged as a result of factor analysis (Difficulty of Science) be further expanded and explored. Specifically, the pool of items measuring perceived difficulty of science should be increased and construct validity and reliability of the instrument verified.

A further refined attitude questionnaire would have merit as a diagnostic tool that science teachers could use in monitoring their students' attitudes toward science. In addressing the topic of student-involved classroom assessment (Stiggins, 2001) comments, "I think *responsibility for school-related affect should rest with us educators*. As a teacher, I hold myself accountable for the dispositions of my students" (p. 343). By using comprehensive, valid, and reliable instruments to diagnose students' attitudes toward science, teachers have an additional resource to supplement their tacit knowledge of ways to meaningfully engage students affectively with the curriculum.

It is shown that learning and interests developed outside school influence learning in school (Murphy, 1997). Therefore, it is important for schools to engage parents as well as to develop diverse forms of cooperation with the broader community (including museums, postsecondary institutions, industries, and research communities) to provide students with varied learning opportunities and experiences and educate them about the social relevance of science and a broad variety of science-based career opportunities. Further research is needed to document and disseminate these experiences and evaluate student outcomes at various grade levels and for various socioeconomic backgrounds.

Notes

1. The views expressed in this article are those of the authors and not necessarily those of Alberta Education.
2. Rotation makes factor structure clearer by maximizing the loading of each item on one factor and minimizing its loadings on the other factors. Oblique rotation (promax) was chosen for factor analysis in this study based on the theoretical reasoning that the factors might correlate. Other orthogonal, rotation methods assume uncorrelated factors. Under pairwise deletion of missing data, cases are excluded only from calculations involving variables for which these cases miss data.
3. Two questionnaire items (Q43—"To do well in science you need to work hard" and Q50-"My parent(s) think learning science is important") were omitted before running factor analysis. The first item was removed to avoid conflicting interpretations by the respondents, who may interpret it as science being too difficult for them or as them being perseverant or motivated in learning science. The second item was removed to focus analysis on students own perceptions of science and learning science. The following additional items were eventually excluded from the factor solution: Q23—"In my science class we ask questions about light," Q24—"Going to science field trips makes me interested in science," Q25—"Science is boring," Q31—"In science we learn how to reduce the waste people create," Q33—"My school has science activities outside the classroom," Q34—"Science is important only to science teachers" and Q54—"Science helps me learn many new things." The decision to remove these items was based on the 0.40 cut-off for factor loadings as well as taking into consideration a combination of factor interpretability and individual items' contribution to Cronbach's alpha reliability.
4. Eigenvalues represent the amount of variance in a set of variables explained by a factor. Thus factors with relatively large eigenvalues (1 and up) are retained, and those with relatively small eigenvalues are ignored.

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Appendix: Survey Questions

We want to find out how you feel about learning science. There are no right or wrong answers; we are only interested in what you think and feel. Your answers will be kept private. Only the researchers will see your answers. You should feel free not to answer any items. Thank you for answering the questions.

1. Are you a girl or a boy? (Circle one)
   GIRL
   BOY
2. Do you use a computer at home? (Circle one)
   YES
   NO
3. Do you use a computer at school outside of class time? (Circle one)
   YES
   NO
4. Do you use a computer at a public library? (Circle one)
   YES
   NO
5. Do you find out about science or nature topics on the Internet using a computer? (Circle one)
   YES
   NO
6. Do you borrow books from the public library? (Circle one)
   YES
   NO
7. Outside of school do you read a book or a magazine about science or nature? (Circle one)
   YES
   NO
8. Do you watch science or nature programs on TV or video? (Circle one)
   YES
   NO
9. Do you do science homework? (Circle one)
   YES
   NO
10. Have you visited any of the following with your family? (Circle ALL places that you have visited)

Odyssium	YES	NO
Provincial Museum	YES	NO
Fort Edmonton	YES	NO
John Walter Museum	YES	NO
Muttart Conservatory	YES	NO
Devonian Gardens	YES	NO
Tyrell Dinosaur Museum in Drumheller	YES	NO

Please describe how you feel about going to school by checking ONE box for each line:
(Boxes correspond to the following answer choices: Strongly agree; Agree a little; Disagree a little; Strongly disagree; I'm not sure)

11. I like going to school.
12. I feel welcome at school.
13. I feel safe at school.
14. I feel sad at school.
15. I feel lonely at school.
16. I get along well with my classmates.

Please describe how you feel about learning science. *(Check ONE box for each line)*
(Boxes correspond to the following answer choices: Strongly Agree; Agree a little; Disagree a little; Strongly disagree; I'm not sure)

17. In my science class we do many different activities.
18. Working together helps everyone on a science project.
19. Science is difficult.
20. I like visiting the Odyssium with my class.
21. I don't do well in science.
22. We have to do too much home work in science.
23. In my science class we ask questions about light.
24. Going on science field trips makes me interested in science.
25. Science is boring.
26. I think scientists have interesting jobs.
27. Science makes me think.
28. In science we learn how to help nature.
29. Visiting the Odyssium makes me like science more.
30. We do too much science at school.
31. In science we learn how to reduce the waste people create.
32. I would like to be a scientist.
33. My school has science activities outside the classroom.
34. Science is important only to science teachers.
35. I like to help other students in my science class.
36. In science we ask questions about the world.
37. Science is harder for me than for other students.
38. I discover a lot of new things during our visits to the Odyssium.
39. I usually do well in science.
40. In my science class we ask questions about how different plants grow.
41. Science is not very important outside of school.
42. In science we learn how to make machines we need.
43. To do well in science you need to work hard.
44. Science helps me understand the world around me.
45. Science is fun.
46. I like to work on science with other students.
47. Going on science field trips helps me better understand how nature works.
48. I am as good at science as most other students.
49. In science we answer questions by doing experiments.
50. My parent(s) think learning science is important.
51. It is hard for me to work on science with other students.
52. I enjoy learning science.
53. Visiting the Odyssium helps me understand science.
54. Science helps me learn many new things.
55. Science is one of my favorite subjects.
56. I learn the most when I work with other students.

Please tell us how you feel about using computers by checking ONE box for each line. *(Boxes correspond to the following answer choices: Strongly agree; Agree a little; Disagree a little; Strongly disagree; I'm not sure)*

57. I like using a computer.
58. I am good at using a computer.
59. I don't enjoy using a computer.
60. I am learning about computers at school.
61. Using a computer helps me do better in science.

Please tell us how do you like to work on science *(Put a check mark in ALL boxes that describe you)*

With the teacher
With my classmates (with a partner)
On my own in class
On my own at home
With help from my parents/guardians

Please write below anything else you would like to say about learning science.