Creating a WEB of Evidence of Student Performance In A Technology-Rich Learning Environment

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In 1995, Vermont received a federal Technology Innovation Challenge Grant through the Montpelier School District called The WEB Project. The grant was written to be a statewide initiative aimed at helping students in Vermont schools demonstrate and improve their mastery of state standards through performance in Vital Results *and two* Fields of Knowledge: *Arts, Language and Literature; and History and Social Sciences (specific sections of the Vermont* Framework of Standards and Learning Opportunities*). The grant was subtitled "Creating a WEB of Evidence of Student Performance in Nonverbal Inquiry and Expression." The project utilized multimedia telecommunications: as an educational environment for student inquiry, expression and dialogue about assigned literary texts; as a medium for presenting and assessing student works of traditional and digital art, music, and multimedia; and as a virtual faculty room for professional discussions about student work.*

"The WEB Project began with a director and core group of teachers who had already done significant, collaborative work using student and teacher work samples as the point of discussion. For the year prior to the WEB Project's federal funding, 28 visual arts teachers participated in personal critique sessions led by a Vermont artist. Teachers then conducted action research studies – guided by a university professor and a soon-to-be WEB Project director – to examine how their professional critique sessions might apply to their classroom practice. While visual arts teachers were working in person, music teachers were developing an Internet-based network for their explorations in critique of student music compositions. Increased popularity of the WWW allowed the music teachers to migrate from an e-mail system based on one-on-one mentoring to a collaborative, online learning environment."

F. Tavalin (personal communication, January 27, 2001)

Guidelines were developed for online dialogue (Tavalin & Boke, 1998) and design conversations (Tavalin, 1998), and teachers

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began to grapple with the knotty problem of designing performance assessments to evaluate student work. Discussions were hosted on The WEB Exchange (**http://www.webproject.org**), a Web-based learning environment hosted on The WEB Project's server.

RMC Research Corporation served as the external evaluator throughout the life of the grant. Realizing that students can learn from web-based instruction, dialogue and design conversations within a virtual learning community (Sherry, 2000; Sherry, Billig, & Tavalin, 2000; Sherry, Billig, Tavalin, & Gibson, 2000), the evaluation team asked, "What forms does this learning take?" and, "How may we measure increases in student achievement in a mediated learning environment?" Thus, although the study presented here took place within the context of rural Vermont schools, we feel that the model that developed as a result of this evaluation can be generalized to any technology-rich educational environment.

METHODOLOGY

A number of converging lines of inquiry were designed to assess the impact of The WEB Project on nine cooperating schools. Quantitative data from surveys and qualitative data from site visits were triangulated with an analysis of online student products.

Site Visits

In spring 2000, site visits were conducted at the cooperating schools. Participating teachers were interviewed. Where possible, homogeneous focus groups of students were conducted; where not possible, individual students were interviewed.

Online Survey

In the spring of 1998, 1999 and 2000, an online survey was administered to all 165 teachers, administrators and online mentors who participated in the project. The questionnaire was structured as a web-based form, hosted on The WEB Project's server. In each year, the preponderance of responses was from teachers. The survey results showed that teachers thought that the greatest impact was on creative writing in the first year, followed by student engagement, use of feedback, time on task and metacognition across years. Based on these results, a connection between student motivation, metacognition, and learning processes that was reminiscent of Sternberg's (1998) *Developing Expertise* model was discovered. This framework became an interpretative guide for additional exploratory analyses of teacher and student reported data.

Student Surveys

A student survey was pilot tested in May 1999. It was designed using the *Vermont Reasoning and Problem Solving Standards* and other schools of thought regarding thinking and learning skills (Sternberg, 1998; Perry, 1992; Gagne & Briggs, 1979; Bloom, Englehart, Furst, Hill, & Krathwohl, 1956). A pair of 10-item school and class motivation measures was added for the spring 2000 academic year. The motivation scale was derived from the literature and from previous work at RMC Research Corporation. The impact of participation in The WEB Project-related activities was measured on a variety of student attitudes, behaviors and skill areas that were identified by participating teachers.

Since the scales derived from the 1999 pilot test had a high level of internal consistency, the survey was administered twice in 2000 to 165 students across the project: once in January as a pretest, and again in May as a posttest. The surveys took an average of 15 minutes to complete, and were primarily composed of closed-ended statements. One hundred thirty-seven of these surveys were from students who had not yet been exposed to The WEB Project activities as an intervention, and could therefore be used as pretest data. Gender was about equally distributed within the sample. About 75% were high school students, and 25% were middle school students. The use of technology within The WEB Project activities was dispersed fairly evenly throughout six academic content areas: Integrated Curriculum (Interdisciplinary), Art, Music, Technology, English/Language Arts and History/Social Studies.

Rubrics to Evaluate Student Process for Creating Products

Many types of learning processes that are facilitated by immersion in a technology-supported, rich environment for active learning (REAL) are not measured by standardized tests. Hence, much of the effort of the participating teachers over the past three years was devoted to developing new types of performance assessment aligned with the activities and learning results that they expected from their students. Teachers were interested in assessing gains in student learning processes as well as scoring their final products.

In keeping with the first objective of the project – namely, to promote in person and online discussions of student work among students, teachers, administrators, and community members that center on the Vermont Framework – a representative group of teachers from the cooperating schools met with the project co-director and a member of the evaluation team to reach consensus on a measure for assessing student learning processes. Teachers discussed several rubrics from Marzano, Pickering and McTighe (1993). Assessing Student

Outcomes collection of performance assessments using the Dimensions of Learning model. Criteria for decision-making included:

(1) how students and teachers actually used The WEB Project technology;

(2) what teachers valued in terms of learning outcomes;

(3) ability to apply to student-generated art, music, and multimedia as well as online dialogue; and

(4) other teacher-proposed criteria.

Using these criteria, teachers selected Reasoning Strategy 13: *Invention, rubric c – "makes detailed and important revisions in the initial process or product"* as the rubric they wanted to use. At the end of the spring term, 143 teachers reported scores for their students on a scale of 1 (low) to 4 (high) based on the selected process rubric.

About 95% of the students reported that they posted products and revised them at least once. Most students posted multiple times. However, based on the messages in The WEB Exchange design conversations, many of the final products were never posted.

Rubric to Evaluate Student Products

Over the past three years, participating teachers were actively involved in developing and benchmarking rubrics to assess student products in digital imaging, multimedia communication, reflection and critique and response to literature. By the end of the spring 2000 term, teachers had benchmarked student work using three rubrics:

(1) Multimedia (and multimedia Web design);

(2) Digital art; and

(3) Online dialogue and music critique.

In May 2000, a representative group of teachers brought their students' products and scores on the three rubrics to the *Basin Harbor Retreat*, an annual project-wide professional development session. During and after the retreat, 141 student products were re-assessed by a team of experts from The WEB Project to increase reliability of the scoring process. After unreliable scores were deleted from the final analysis, the raw score on each rubric was translated into a scale that spanned all types of student products. The scale ranged from 0 (no evidence), 1 (approaches standards), 2 (meets standards), to 3 (exceeds standards).

RESULTS

Prior Experience with Technology

It was important to assess participating students' prior experience with multimedia and online discussions because students who were taking the pre-test survey prior to the intervention – WEB Project-related activities infused into an academic subject area during the spring 2000 term – might not necessarily be starting out with zero technology knowledge and skills.

About half of the 165 students (52.1%) who answered the survey question about prior experience with multimedia or about online discussions indicated that they had used multimedia for at least one year. This is not surprising, since students in the cooperating schools have been participating in The WEB Project-related activities for two to five years.

Table 1. Perceived skillimprovement over time (N = 169)

Skill	Before	Now	*F**	*df*	*p***	Eta***
a. Create a multimedia project	2.76	3.60	108.6	1,138	.000	.663
b. Use a video camera	3.25	3.79	44.44	1,140	.000	.491
c. Send and receive e-mail	3.79	4.09	15.50	1,147	.000	.308
d. Search for info on the WWW	3.89	4.17	12.72	1,150	.000	.279
e. Create or edit a WWW site	2.16	3.21	64.98	1,129	.000	.579
f. Send and receive files over the Internet	2.94	3.52	38.75	1,144	.000	.460
g. Compose music electronically	2.36	3.23	46.79	1,134	.000	.508
h. Create or edit digital art	2.50	3.53	93.15	1,134	.000	.640
i. Scan materials	2.79	3.85	92.09	1,137	.000	.634
j. Participate in online discussions	2.98	3.61	53.59	1,122	.000	.552

* Test for statistical significance ** Statistical significance level *** Correlation coefficient-based effect size

Note: Cohen (1988) considers an effect size of 0.1 to be small, 0.3 to be moderate, and 0.5 to be large.

IMPROVEMENT IN STUDENT ACHIEVEMENT

The overarching goal of The WEB Project is to improve student performance. To document improvement in student performance over time, specifically regarding skills that are honed by participating in The WEB Project activities, three analyses extracted from RMC Research's (2000) *The WEB Project: Evaluation* are presented:

- Representative results from the student surveys;
- Teacher and administrator perceptions reported in the online survey; and
- The relationship between learning processes and outcomes.

The correlations between motivation, metacognitive skills, learning processes and student performance using an expanded version of Sternberg's (1998) *Developing Expertise* model are also presented as a way to explain some of the patterns found in the data.

REPRESENTATIVE RESULTS FROM THE STUDENT SURVEYS

Improvement Over Time

Students were asked to identify their skill level along 10 dimensions before and after participation on a five-point Likert-type scale (1 = "could not do it;" 5 = "expert, the best!"). A multivariate analysis of variance (MANOVA) was performed, along with follow-up *F*-tests to determine significance levels. Table 1 presents the students' perceived skill improvement over time. Higher mean scores indicate student perception of higher skill level. There were statistically significant differences ($p < .05$) between the before and after skill levels for all skill items.

Clearly, The WEB Project resulted in students acquiring a range of specific technology skills. The smallest differences were in students' capabilities in using the World Wide Web. Many students already had this skill. The largest differences were in creating multimedia projects, in creating or editing digital art and in scanning materials.

Learning New Skills

Using a Likert scale, students were asked the degree to which they believed they acquired new skills as a result of participation in The WEB Project-related activities. Table 2 presents the relative percentages of student responses to these questions. In each case, more than three-quarters of the students either agreed or strongly agreed that they were learning new skills, were given more approaches to be creative, were better able to communicate and were better able to visualize ideas.

Transfer of Skills

Students were asked whether they were able to use what they learned with technology either in another class or outside of school. Most of the 144 students who answered this question (82.3%) reported that they used their newly acquired skills outside of class. This was affirmed in the interviews and focus groups in which students: reported that they produced multimedia reports or reports with digital graphics for other core courses; were members of multimedia clubs; participated in multimedia festivals; and/or used their skills for job-related activities or portfolios for entrance to college.

Teacher and Administrator Perceptions of Student Behaviors

Online Survey Results

In the online surveys that were administered in the spring of 1998, 1999 and 2000, teachers, administrators and mentors were queried about the impact of The WEB Project as a whole on student performance. Eight indicators of student

Table 2. Students' perceptions of degree of learning new skills

New Skill	Strongly Agree	Agree	Disagree	Strongly Disagree
I am learning skills that will be useful in the future. (N=163)	47.2%	44.8%	4.9%	3.1%
I am learning skills that I can use for other creative activities. (N=161)	38.5%	55.3%	4.3%	1.9%
I have more opportunities to be creative. (N=162)	36.4%	51.2%	9.9%	2.5%
I am better able to communicate my ideas to others. (N=156)	22.4%	69.9%	6.4%	1.3%
I am better able to picture in my mind ideas and concepts taught in this class. (N=158)	20.9%	62.7%	13.9%	2.5%

performance were listed, and their degree of influence was measured using a four-point scale: 1 (not at all), 2 (slight), 3 (moderate) and 4 (a lot). The results of the analysis of the four-point scale described are displayed in Figure 1.

The pattern of results for three of the eight subscales over the three-year period during which teachers observed and reported these effects indicated that the effect was higher at first, then lower, and then tended to rise again. Often, when new technology is introduced, there is a learning curve that lowers performance before the desired student skills begin to increase again. In essence, respondents feel confident in their knowledge and skills, then discover what they do not know and feel less confident, then learn the skills, feeling competent again. Moreover, in The WEB Project, teachers and students were co-learners. In other words, teachers needed to learn what behaviors to identify and observe and often needed to learn along with their students.

From an analysis of the online survey responses over the three-year period, it also became apparent that teachers were seeing improvements in student behaviors in a time sequence. They tended to observe increases in *student engagement* and *time on task* early in this sequence. These behaviors may be interpreted as indications of student motivation. Teachers observed *use of constructive feedback* and increased *metacognitive skills* early in the time sequence. These behaviors may be interpreted as strategic thinking skills. *Depth in reports* emerged still later in the time sequence. This is an outcome of higher order thinking skills. Finally, most teachers thought it was "too early to tell" about improvements in *student grades* and *test scores*. These are traditional learning results that are more easily measured, but that do not necessarily capture the value that technology adds to the learning process.

Relationship Between Processes and Student Outcomes

Motivation

According to Sternberg (1998), motivation drives metacognition that, in turn, stimulates the development of thinking and learning skills. Thinking and learning skill development further stimulates metacognition, resulting in the development of expertise. Thus, it was important to measure students' self-reported levels of motivation, both in their WEB Project-related class and in school in general, to carry out structural equation modeling later on, using the Sternberg model as a theoretical framework.

Ten items related to student motivation "in this class" and "in school in general" were identified. Students were asked to rate how they felt about their WEB Project-related class on a five-point, Likert-type scale (1 = "strongly disagree;" 5 = "strongly agree"). A factor analysis was performed on the 10 pretest items, which resulted in two distinct factors. The seven items in the first factor were used as a scale for further analysis, and the remaining three items were dropped. Internal consistency reliability for all seven items in the motivation scale was high (see Table 3). The post-test results are presented in Tables 4 and 5.

The results for the classroom and school were compared. Paired-samples *t*-tests were conducted on the seven-item motivation scales. The pretest and posttest mean values for items addressing initiative, responsibility, effort and hard work were significantly different. This indicates that students tend to be more engaged in The WEB Project classes than they are in other school activities. Results of the paired-samples *t*-test are presented in Table 6.

Metacognition

Reviewing the research literature, eight metacognitive skills were identified as being rel-

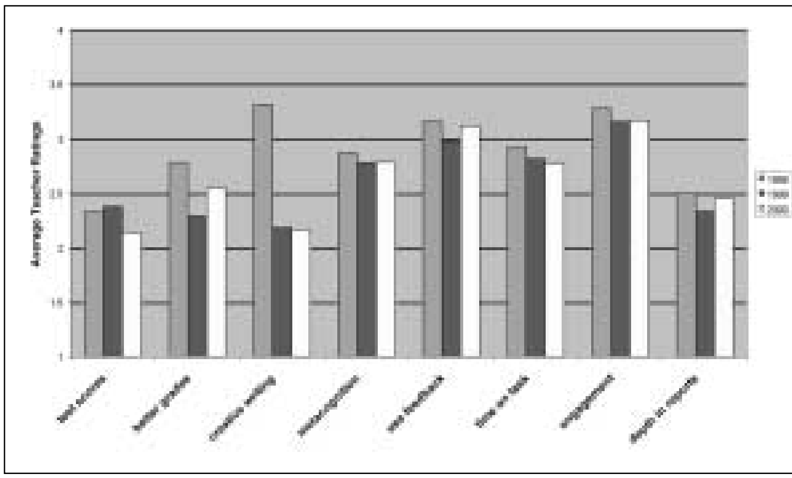

Figure 1. Teacher perceptions of student behaviors

Table 3. Pre-test/post-test internal consistency reliability for scales used in exploratory analyses (coefficient alpha)

Scale	Pre-Test		Post-Test	
	N	Alpha	N	Alpha
Motivation "in school in general"	103	.8339	158	.8594
Motivation "in this class"	97	.8177	157	.8095
Metacognition	103	.8725	157	.8934
Inquiry Learning	102	.8006	165	.7480
Application of Skills	100	.6962	162	.6147

Table 4. Student motivation "in this class"

Motivation Item	Mean Value*	Stdev
I have initiative. (N=155)	3.67	.83
When I take on new responsibilities, I follow through and complete them. (N=158)	3.72	.73
I believe I am intelligent. (N=158)	3.84	.87
I try to do my best. (N=159)	3.96	.78
I work hard. (N=157)	3.89	.81
I have confidence in myself. (N=159)	3.84	.75
I am satisfied with who I am. (N=158)	4.06	.85

* Average scores are on a five-point scale. Higher values indicate greater motivation.

Table 5. Student motivation "in school in general"

Motivation Item	Mean Value*	Stdev
I have initiative. (N=155)	3.40	.85
When I take on new responsibilities, I follow through and complete them. (N=158)	3.56	.77
I believe I am intelligent. (N=158)	3.77	.84
I try to do my best. (N=159)	3.77	.84
I work hard. (N=157)	3.73	.92
I have confidence in myself. (N=159)	3.81	.78
I am satisfied with who I am. (N=158)	4.00	.84

* Average scores are on a five-point scale. Higher values indicate greater motivation.

Table 6. Results of paired sample t-test for motivation scales

Subscale	*t*-Value	*df*	Two-tailed Significance*
I have initiative.	4.054	154	.000
When I take on new responsibilities, I follow through and complete them.	2.867	157	.005
I believe I am intelligent.	1.294	157	.198
I try to do my best.	2.961	158	.004
I work hard.	2.211	156	.028
I have confidence in myself.	.610	158	.543
I am satisfied with who I am.	1.039	157	.300

*Statistical significance level ($p<.05$)

evant for students who used technology in their work with art, music, multimedia or online discussions. These are listed in Figure 8. Students were asked how often they used metacognitive skills – as measured by the subscale – as they used technology to support their activities in art, music, multimedia and online in their WEB Project-related activities. There were four levels: 1 (never), 2 (seldom), 3 (often) and 4 (a lot). Internal consistency reliability for all eight items was high (see Table 3).

Three other scales were also derived from the student survey data. Metacognition was measured using eight items. Learning processes consisted of two distinct factors – inquiry learning (four items) and application of skills (six items). These two scales were derived from the 10 items in survey question 7. Internal consistency reliability for all of these scales was fairly high and remained relatively stable between the pre-test and the post-test.

Learning Processes

These data show that students recognize that they engage in some metacognitive skills, particularly changing/improving ideas and products and retrieving information. The large range in responses is related to the type of WEB Project activity in which the students engaged. For example, students in the arts and music programs were expected to post products, receive feedback and revise. This was an occasional occurrence as product creation warranted, so the responses most likely reflect the reality of The WEB Project experience.

Students were asked how often they used technology for a list of 10 common technology-related activities using a four-point scale, ranging from a 1 (never), 2 (seldom), 3 (often) to 4 (a lot). These activities were grouped into two factors that were named *application of skills* and *inquiry learning*. Internal consistency reliabilities were fairly high for both scales (see Table 3). The items that make up these two subscales are shown in Tables 8 and 9. They are indicative of learning processes.

These Tables show that students most often engage in design and communication functions and in a range of inquiry-based activities. Again, this was related to the nature of The WEB Project activities in which students participated. Fostering online communication was one of the overarching aims of The WEB Project. Conducting research was highly encouraged by interviewed teachers and was an integral part of their curriculum.

"Show ideas" refers to demonstrating student learning. Several teachers in core curriculum areas reported that they gave their students the option of using technology-supported presentations for their final projects, rather than the usual oral or written report. They also mentioned that students who created multimedia final projects generally received higher grades than those who demonstrated their learning by more traditional venues.

Learning Results

Student Product Assessment scores were discussed and juried at the Basin Harbor Retreat by experts in the discipline area who developed rubrics through the establishment of anchor products. Three raters scored products. Scores that were not deemed reliable were not used in this analysis. Since the rubrics for the individual content areas had different ranges, the raw scores were translated across academic content domains from a scale of 0 (no evidence), 1 (approaches standards), 2 (meets standards) to 3 (exceeds standards). One hundred forty-one student products were scored. Table 10 presents the distribution of Student Product Assessment scores.

Student Learning Process Assessment scores were reported by 143 of the participating teachers. The rubric has a range from 1 (little revision) to 4 (very detailed and important revisions). Results are reported across the project in Table 11.

Table 12 presents the mean values and standard deviations for the scores for those students who had not been exposed to the intervention as of January 2000, and which were used in the exploratory analysis.

Across the project, students nearly met the standards for the Student Product Assessment. Students also nearly met level 3 of the Student Learning Process Assessment, namely, "Revises the process or product in ways that serve the purpose of the process or product."

To see whether improvement occurred and was sustained over time, 76 valid data sets were matched, and a true repeated measures paired sample *t*-test methodology (pretest vs. posttest) was conducted. A two-tailed *t*-test was used because it was predicted that the mean value of all of these subscales would increase from the pretest to the posttest. Data were filtered on "midpoint," i.e., only classes that started in January 2000 (no prior intervention) were analyzed.

The results are displayed in Table 13 for the key subscales of interest. The only subscale that showed significant improvement over the spring term was application of skills. Class motivation declined slightly, but this may have been affected by the timing of survey administration since many students are generally less motivated at the end of the school year.

Table 7. Metacognitive skills related to the Web project

Metacognitive Skill	Mean Value*	Stdev
Get information from places I can count on (N=169)	2.75	.83
Try different ways to solve a problem (N=167)	2.25	.96
Get reasons for my answers (N=158)	2.31	.94
Make sure my answers are right (N=167)	2.33	.93
Find patterns (N=165)	2.05	.90
Make connections (N=166)	2.37	.94
Make a sketch or picture to show a problem or idea (N=167)	2.19	1.05
Change or improve my idea or product (N=167)	2.65	.95

* Average scores are on a four-point scale. Higher values indicate greater use of Metacognitive Skills.

Table 8. Application of skills related to the Web project

Application of Skills	Mean Value*	Stdev
Design graphics (N=167)	2.53	1.18
Communicate with others (N=168)	2.91	.95
Take part in simulations (N=166)	1.84	.91
Make models (N=165)	1.77	.97
Build websites (N=167)	1.82	1.05

* Average scores are on a four-point scale. Higher values indicate greater Application of Skills.

Table 9. Inquiry learning related to the Web project

Inquiry Learning	Mean Value*	Stdev
Do research (N=168)	2.79	1.01
Get ideas (N=166)	2.63	.85
Show ideas (N=166)	2.83	.91
Solve problems (N=168)	2.20	.93

* Average scores are on a four-point scale. Higher values indicate greater Inquiry Learning.

Table 10. Distribution of student product assessment scores for all participating students (N = 141)

Score on Student Product Assessment Rubric	Percentage of Students
0: No Evidence	0%
1: Approaches standards	29%
2: Meets standards	40%
3: Exceeds standards	31%

EXPLORATORY ANALYSES

Last year, an initial path analysis of WEB Project data yielded a promising set of hypotheses to explain influences on student outcomes. Figure 2 depicts the model that was used for the path analysis. The values for the arrows connecting metacognition and inquiry learning, and metacognition and application of skills, represent partial correlations. The 1999 results indicated that metacognition had a moderate to strong ability to predict learning processes (inquiry learning and application of skills). However, at that time there were no measures of motivation on achievement.

With the inclusion of the student motivation measures, the Student Learning Process Assessment and the Student Product Assessment, a more sophisticated model could be derived and tested. Structural equation modeling was used to find the partial correlations between motivation, metacognition, inquiry learning, application of skills, the Student Learning Process Assessment and the Student Product Assessment. The results are presented in Figure 3.

The results of the intermediate analyses that produced the correlations presented in Figure 3 (the previous Figure) are presented in Tables 16

Four separate simplified path analysis models were tested. The first pair addressed progress and product outcomes for classroom motivation, and the second pair addressed school motivation. Motivation is related to metacognition. The relationship between class motivation and metacognition was slightly stronger than the relationship between school motivation and cognition.

The relationship between metacognition and inquiry learning was stronger than the relationship between metacognition and application of skills. Also, the relationship between inquiry learning and the student achievement process outcome was stronger than the relationship between application of skills and the student achievement process outcome. Finally, the relationship between application of skills and the student achievement product outcome was stronger than the relationship between inquiry learning and the student achievement product outcome.

Based on the significant correlations of the teacher measurements of student achievement with the student survey data, these data validated the *Developing Expertise* model, to explain increases in student performance as a result of engaging in WEB Project-related activities.

DISCUSSION

The *Secretary's Conference on Educational Technology 2000* focused on several important issues regarding student achievement. In particular, questions such as, "What added value does technology bring to schools?" and, "What assessment strategies and designs are currently being used to capture the added value that technology brings to schools?" The President's Committee of Advisors on Science and Technology (1997) listed three goals for student outcomes:

Table 11. Distribution of student learning process assessment scores for all participating students (N = 143)

Score on Student Learning Process Assessment Rubric	Percentage of Students
1: Makes few, if any, attempts at revision.	6%
2: Revises, but addresses only the most obvious difficulties.	28%
3: Revises in ways that serve the purpose of the product.	28%
4: Revisions are likely to produce a high quality product.	38%

Table 12. Teacher-reported scores of student achievement

Measure	Mean Value	Stdev
Student Product Assessment (N=91)	1.978	.760
Student Learning Process Assessment (N=107)	2.785	.906

Table 13. Results of paired samples *t*-test for pre/post test subscales

Subscale	Pre-Test Mean Value	Post-Test Mean Value	*t*-Value	*df*	Two-tailed Significance*
School Motivation	3.783	3.771	.141	66	.444
Class Motivation	4.05	3.925	-1.468	61	-.0735
Metacognition	2.219	2.268	.812	73	.210
Inquiry Learning	2.409	2.463	.791	74	.216
Application of Skills	1.767	1.898	2.172	74	.0165 *

*Statistical significance level (p<.05)

- Richer, deeper content, mastered earlier in the curriculum;
- Attainment of higher-order cognitive, affective, and psychosocial skills; and
- Success for all students.

Rockman (1998) suggests, "A clear assessment strategy that goes beyond standardized tests enables school leaders, policy makers and the community to understand the impact of technology on teaching and learning." Using a research-based framework such as the Sternberg model to organize and interpret the variety of student self-perceptions, teacher observations of student behaviors and juried scoring of student products using teacher-created rubrics, captures the overlapping kinds of expertise that students are developing in their WEB Project-related activities.

These preliminary findings suggest that teachers should emphasize the use of metacognitive skills, application of skills and inquiry learning as they infuse technology into their academic content areas. This is directly in line with the *Vermont Reasoning and Problem Solving Standards.*

The findings also indicate a lack of impact on traditional measures of student achievement. However, as Dede (1998) stated, "To succeed in technology-based educational reform, state policy makers must prepare communities for the fact that test scores will not instantly rise and that other, complementary types of improvements in student outcomes less easy to report quantitatively are better short-range measures of success."

CONCLUSIONS

In the final three years of the project, the teacher responses regarding time on task and greater engagement signaled greater motivation among students, especially because students reported spending many hours learning and applying new skills. For the most part, student interviews and focus groups showed this was done willingly and not because of the demands of the instructor. The technology, itself, motivated them.

Moderately high rankings for metacognitive skills such as "get information from places I can count on" and "change or improve my idea or product" indicate that students were evaluating the quality of the information they find on the Internet, The WEB Exchange, and other primary sources. They were also reformulating strategies to improve their work. Moreover, the fact that nearly all students across the project met the standards for both the teacher-created product assessment and the learning process assessment indicates that, in general, the project did have a positive impact on student achievement.

One of the greatest challenges facing the Technology Innovation Challenge Grants and

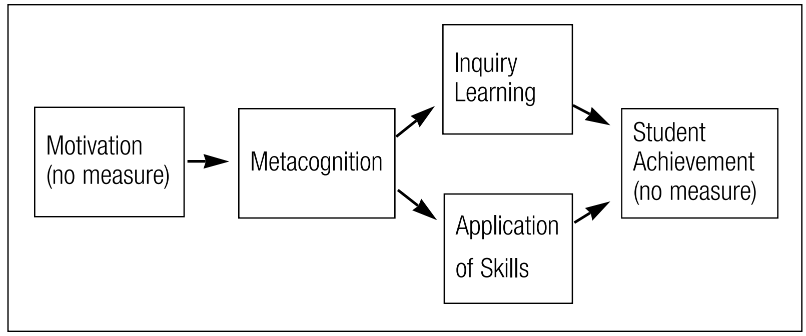

Figure 2. Initial path analysis results (May 1999)

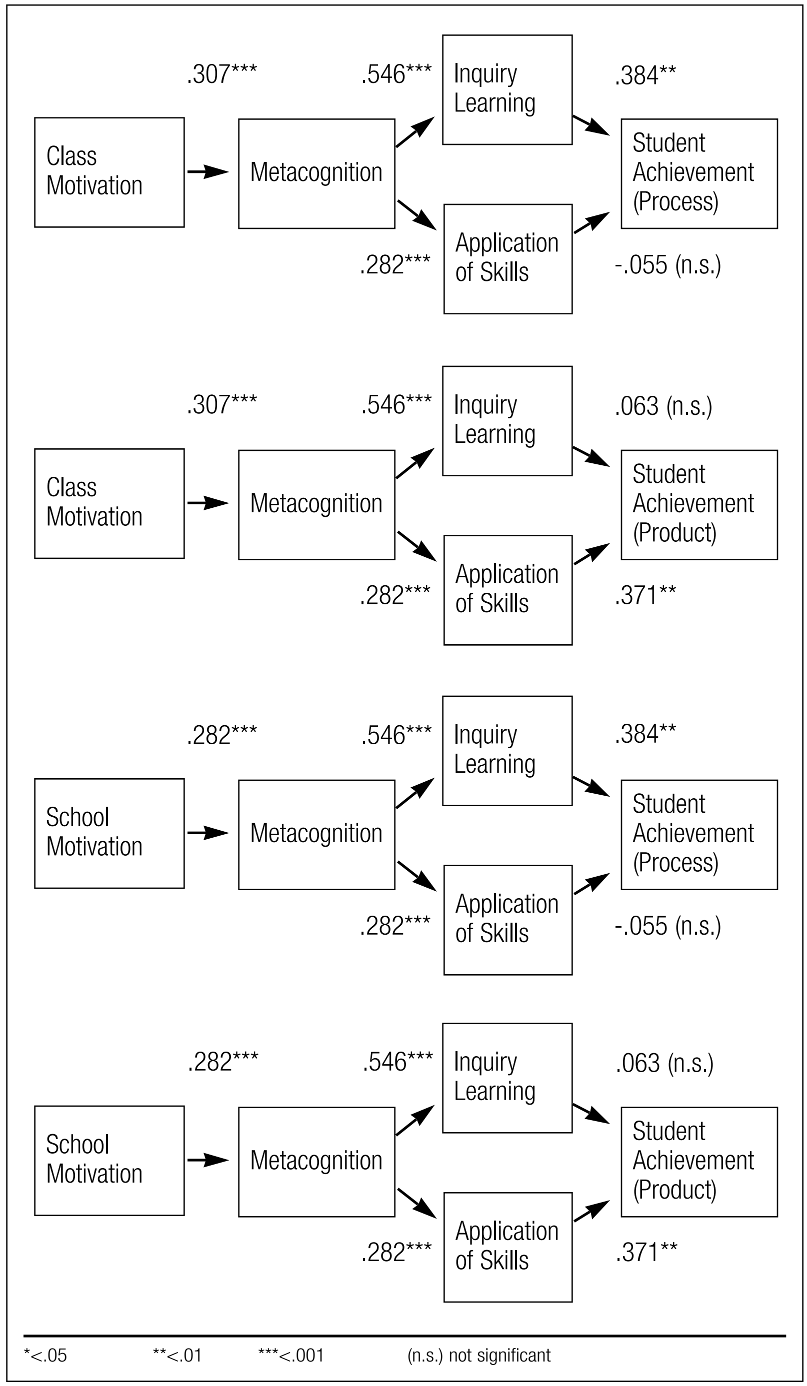

Figure 3. Simplified path analysis showing influences on student achievement

the Preparing Tomorrow's Teachers To Use Technology (PT3) grants is to make a link between educational technology innovations – promising instructional practices using technology and increases in student achievement. We believe that this model shows promise to replicate in other educational institutions, including schools, districts, institutions of higher learning and grant-funded initiatives. However, to use this model, participating teachers must be able to clearly identify the standards they are addressing in their instruction; articulate the specific knowledge and skills that are to be fostered by using technology; carefully observe student behavior in creating and refining their work; and create and benchmark rubrics that they intend to use to evaluate student work.

Table 16. Regression analysis: motivation-> metacognition

Dependent Variable	R	*F*	*df*	Two-tailed Significance*
Motivation in this class	.307	16.539	1,159	.000
Motivation in school in general	.282	13,698	1,157	.000

* Statistical significance level (p<.05)

Table 17. Anova: metacognition-> learning processes

Dependent Variable	Beta*	*t*-value	Two-tailed Significance**
Inquiry Learning	.546	8.362	.000
Application of Skills	.282	4.313	.000

* Standardized correlation coefficient
** Statistical significance level (p<.05)

Table 18. Regression analysis: learning process->learning outcomes

Independent Variable	Dependent Variable	Beta*	*t*-value	Two-tailed Significance**
Inquiry Learning	Process Assessment	.384	3.295	.001
Application of Skills	Process Assessment	-.055	-.473	.637
Inquiry Learning	Product Assessment	.063	.504	.615
Application of Skills	Product Assessment	.371	2.986	.004

* Standardized correlation coefficient
** Statistical significance level (p<.05)

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