

Demystifying data about technology impacts in schools

Ravitz, J. (2002). National Educational Computing Conference (NECC). San Antonio, TX.

Audience This NECC 2002 paper is for educators who wish to measure the impacts of technology in schools. It should be of interest to:

- principals, administrators, and technology-coordinators,
 - technology-using educators,
 - researchers, policy makers, funders, and
 - those who are held accountable for technology integration.
-

Purpose The purpose of this document is to help educators communicate effectively about the impacts of their technology use. It presents the “error model” of research as a way to approach evidence about technology impacts and provides examples from several studies.

Policy context Educational policy makers, like others in government, are feeling a push towards “evidence-based” decision making and greater accountability. While some see opportunities to create better learning environments through better use of data, the upshot is that public schools and teachers are increasingly being asked to produce measurable evidence of student outcomes. Recipients of funding for technology are particularly in trouble if they cannot produce findings in a convincing fashion or respond to critics with evidence of student learning.

Importance Because discussions about technology-related data will have impacts on teachers and students, it is important for educators to know how to respond to and use data more effectively.

Topics This paper is organized around these topics.

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Using the prediction game to understand error

Goals for this section

This section introduces essential research principles in a manner that can be useful for everyday discussions.

It is important to identify the limits of findings and possible sources of error, and steps that can be taken to reduce the chance of error.

What is the error model?

The error model is a way of thinking about knowledge. It often provides the foundation for scientific inquiry and statistical analysis. The key characteristics of this approach include ruling out alternative explanations and addressing sources of error prior to drawing conclusions.

The inverse relationship between error and knowledge is shown here.

If you have...	...the chance of an erroneous conclusion is...
to make a blind guess	very high; only a lucky guess will be right
a little useful knowledge	slightly less, but still a large chance of being wrong
more useful knowledge	even less, you have a greater chance of being right
complete knowledge	zero error, you will be certain of your explanation.

Textbook evaluation example

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Imagine you have a textbook. As the saying goes -- You cannot judge a book by its cover! You might want to review the table of contents as well as the cover. To be more careful, you would want to read particular parts that you deemed to be most important.

As you collected more information you would feel more confident in making a judgment about the quality of the book. Additional investigations might focus on how the textbook is intended to be used, and how it is actually used in the classroom. It may be effective for some purposes and not for others. If you had different criteria for quality you might draw different conclusions.

The more you know about the textbook and its use the better idea you can have of its usefulness for teachers and learners.

Using the prediction game to understand error, Continued

Prediction game: defined

The prediction game is an easy way to think about statistics and the research process using the error model. It demonstrates this guiding principle:

The better information and better knowledge about a topic you have the fewer errors you will make.

Note. This game does not mean you have to go around predicting things. It means if you were making an important prediction you would want to consider possible sources of error and gather information to help you avoid making these errors.

Playing the game: height

Imagine this. Across the room there is a person whose identity is concealed by a dark screen. You know *nothing* about who the screen conceals and you cannot see the person at all.

If you had to make your best guess, what strategy would you use to guess this person's height? Remember, you know *nothing* about this person.

Note: This is the same as making your best guess about the impact of technology in schools, if you had no data. We will return to this later.

Blind guesses

If you really know *nothing* about the concealed person, does that mean that *any* guess is as good as any other?

Actually, your best guess would be whatever the "average" person's height was. It would be very difficult to guess otherwise without any additional information.

Note. A lucky guess is always possible, but this is not an indication of knowledge. You would not want to rely on a lucky guesses when making an important decision. If you had a better information or knowledge you could reduce your average error of prediction over multiple tries.

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Using the prediction game to understand error, Continued

Asking for better information

What information would you want in order to make an “educated” guess about height? Would you want to know if the person is --

- a male or female?
- how tall their parents are?
- if they want to be a professional basketball player?

How confident are you that this information would this help you guess this person’s height more accurately? What if you found out the person is only six years old?

Note. The usefulness of one piece of information can depend on another. In this case, knowing age is more essential than knowing parents’ height; with knowledge of both you could improve your accuracy.

Relationship: Defined

A **relationship** is present between two variables when knowledge of one allows you to make a better prediction of the other than you could make without that knowledge. In the above example, age is related to height.

Understanding statistics using the error model

Many statistics that address relationships have a percent reduction in error (PRE) interpretation. This indicates how much better your predictions are with knowledge than they would have been without knowledge, or by chance alone. Statistics that can be interpreted in this way all have the same basic form:

$(\text{Error without knowledge} - \text{Error with knowledge}) / \text{Error without knowledge}$

These statistics show how much better your predictions are than they would have been by chance alone. The reduction in error is expressed as a percent of the total error, or variance.

Examples of statistics with PRE interpretation include r-squared for correlations and multiple regression.

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Using the prediction game to understand error, Continued

Numbers do not speak for themselves

Data and numbers do not “speak for themselves.” Statistics can tell you if a relationship exists, in what direction, and how strongly. No statistic can tell you what a relationship means.

Data can tell you	You need to think...
<ul style="list-style-type: none">• does a relationship exist,• in what direction,• how strong is it?	<ul style="list-style-type: none">• what does it mean?• is it important?• is it causal?

Spurious relationships

A **spurious** relationship is one that exists between two variables but is caused by a third variable.

Easy example: You observe that Father Curtis always goes walking when it rains and then you find out that people go to bars more frequently when it rains too. Can you conclude Father Curtis is responsible for more people drinking? No. It may be the rain, not his walking, that causes both. This would create the appearance of a relationship when it is only “spurious”.

Turning to educational technology

What about educational technology?

This section shows how to apply the error model and prediction game to educational technology research. It assumes our most pressing question is how to most confidently characterize technology impacts among teachers, students and schools.

Applying the error model, schools

The error model begins by asking -- **in order to confidently characterize technology impacts in schools, what would you want to know?**

Imagine you meet a stranger who is a school principal. What would you ask to determine as quickly and confidently as possible the extent and impact of technology use in her school? List your top 3 questions –

- a. _____
- b. _____
- c. _____

How would the answers to these questions improve your knowledge?

How *confident* are you that with this information you would understand the role technology is playing and its impact on learning?

Note. It might be helpful to write down and discuss your answers with others.

Choosing forest or trees?

There may be some teachers, students or schools who use technology effectively to improve learning results, while others do not. These others may use technology ineffectively, actually hurting the chances of learners. If this were the case, the *net* result would be no difference.

Would that be the most accurate story to tell?

This is the age-old problem of “the forest and the trees.” You cannot *simultaneously* look at the big picture and focus on a smaller section at the same time! If you are a policy maker, funding technology use broadly, asking about net effect might be useful, at first. Eventually you would want to increase your knowledge and look for the type of information that would allow you to improve your investments.

Think -- What question would you ask if it was NOT about the net effect of technology?

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**Students,
teachers and
schools**

One particular forest-tree kind of problem is whether to look for impacts at the school, teacher or student level. It is difficult to focus attention on school scores, teacher scores, and student scores all at the same time. What would you focus on?

**Limited
resources and
trade offs**

Depending on what data is deemed relevant, one can tell very different stories about technology use in schools. No single set of numbers can ever tell the whole story. Data is always collected or presented *selectively*. Remember to ask yourself:

- What question is being asked (about schools, teachers or students)?
 - Is this the right question?
 - What can help you answer the question more confidently?
-

**No easy
answers**

Applying the error reduction idea in educational technology is particularly difficult for several reasons. Unlike height, which only requires a single measure to achieve an answer, educational technology research involves relationships between multiple measures. In addition, the measures in education are “fuzzier” and people have different ideas about how to think about technology impacts.

As a result, there is no “one answer” for the impact of technology. The answer depends on a variety of conditions and there are multiple relationships that can be examined. It is important to be as clear as possible about what is being asked, what is being concluded and what are possible sources of error.

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Applying the model: Technology use

Purpose This section of the paper provides examples of findings educators might want to consider as they discuss the impact of technology on teaching and learning in their schools.

Studies being presented The error model provides a basis for understanding findings from three completed survey studies.

The first two studies were federally funded. Both the National School Network, 1997 and Teaching, Learning & Computing , 1998 tried to predict teacher computer use from their beliefs and practices about teaching.

A later 2002 study in Idaho was funded by the J.A. & Kathryn Albertson's Foundation. It tried to predict student achievement from their computer use.

Predicting teacher technology use The first few two demonstrate a number of factors, beside teacher technology proficiency, that are related to computer use with students. These include:

- Grade level taught
- Subject taught
- Access to technology in different locations
- Time for planning and use with students
- Reasons for use and perceived benefits
- A constructivist-compatible philosophy
- Involvement with peers and professional activities

Evidence of the importance of these conditions is provided below, showing that the more of these conditions that are known, the better one can anticipate teacher technology use.

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Applying the model: Technology use, Continued

Grade level taught

Computer use often varies by grade level taught. Variations are seen in the

- types and amounts of use, and
- the reasons given for this use.

Elementary teachers of self-contained classrooms use computers more often with students. This is probably because of the additional **time** they have with the same students. This allows swapping of students onto computers over the course of the day. Teachers also more often report basic skills development objectives in earlier grades, as shown in the following table.

Percent of teachers using software 3 or more times, by grade taught

Grade	N	Accelerated Reader	Word Processing	Games	World Wide Web	Data Visualization
4	304	99	84	75	57	15
8	397	39	60	22	51	23
11	1030	05	66	14	57	34

Source: Idaho study (2002).

Top objectives for student computer use, by grade taught

Objectives listed among the top 3 for software use with students...	Percent of computer users choosing, by grade		
	4th	8th	11th
Finding out about ideas and information	73%	68%	70%
Learning word processing skills	53	28	21
Learning computer skills	49	35	33
Analyzing information	7	39	49
Mastering academic skills just taught or remediating skills	40	30	31
N	307	420	663

Note. Only objectives with 40 or more percent in any grade are shown.

Source: Idaho study (2002).

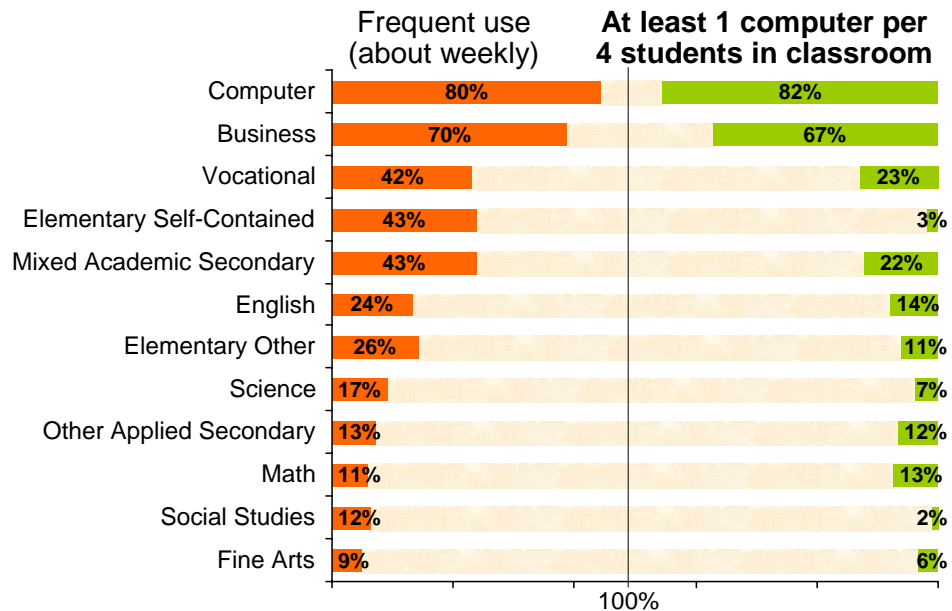
Note. For national response patterns among teachers, see Becker, Ravitz & Wong (1998).

Applying the model: Technology use, Continued

Subject taught Another useful predictor of technology use is subject taught. Use occurs most frequently in subjects where there tend to be clusters of several computers and where the subject matter may be more conducive to regular computer use.

82% of computer teachers have at least 1 computer per 4 students, and 80% use computers weekly with students. In contrast, only 2% of social studies teachers have this level of access in the classroom. Only 12% use computers weekly with students.

Frequent Use & Classroom Access by Subject



Source: Teaching, Learning & Computing: 1998 (Becker, 2000)

Note. When reading percents, it is important to keep in mind the different number of teachers. A large percent of computer teachers is still a relatively small number compared to the number of academic teachers within a school.

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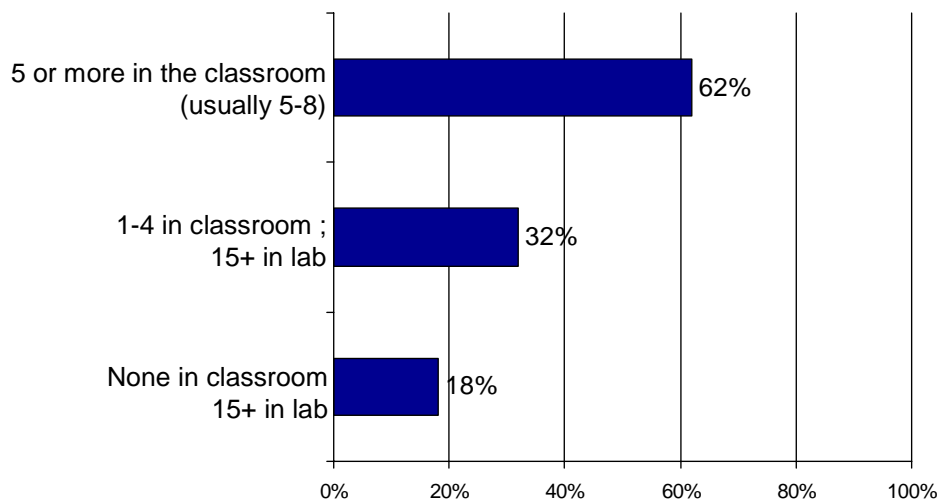
Applying the model: Technology use, Continued

Focusing on technology access

Our earlier analysis showed that subject taught can be an important predictor teacher use and access. In the next figure, we focus only on academic teachers. This removes possible error due to the presence of computer teachers and elementary teachers. (Alternatively, we could have run the same analysis for each subject individually).

The next figure shows that among academic teachers, it is those who have a cluster in the classroom who use computers the most with students.

Frequent Computer Use Occurs More Often with 5-8 Computers in a Classroom than with 15-30 in a Computer Lab (data for Secondary Academic Teachers)



Source: Teaching, Learning & Computing: 1998 (Becker, 2000)

Applying the model: Technology use, Continued

Time

Technology skills are very important, but only part of the equation!

In the National School Network study (1997) the most frequent Internet users with students were those who reported sufficient knowledge and skills AND who reported sufficient availability of time for planning in the schedule and flexibility in the curriculum.

This table shows conditions of knowledge and time availability and the resulting measures of Internet use professionally and with students.

If teacher technology skills are...	and reported time availability is..	teacher professional use is....	and use with students is...
Low	Low	Low (-.61)	Low (-.30)
Low	High	Low (-.45)	Low (-.23)
High	Low	High (.47)	Average (.02)
High	High	High (.57)	High (.43)
All teachers		.00	.00

Note. Teachers were assigned so there would be 25% in each row, N=238. Mean = 0.00 S.d. = 1.00. Source: National School Network (Ravitz, 1999)

Reasons and objectives for use

Another key predictor of use is whether or not a teacher has sufficient reasons or objectives for using technology. In particular, teachers are motivated when they perceive students will benefit from their efforts to use technology.

A measure of “perceived utility” that included various reasons for using the Internet was the only measure that predicted both teacher professional Internet use and use with students in the above study (Ravitz, 1999). Reasons for use is more compelling as a predictor of use than knowledge and skills, for several reasons. Proficiency is more likely to be seen as an end in itself, so it is better to focus on understanding of the reasons for use, rather than the skills required for that use. In addition,

- Skills without reasons for applying them are fairly useless.
- Skillful technology use generally involves multiple uses which are employed for different reasons (so the more reasons, the more use).
- Placing an emphasis on reasons for use suggests the possibility of equally legitimate reasons for *not* using technology under certain circumstances.
- Skeptics will be happier when educators are better able to articulate their reasons for using technology and the benefits for students.

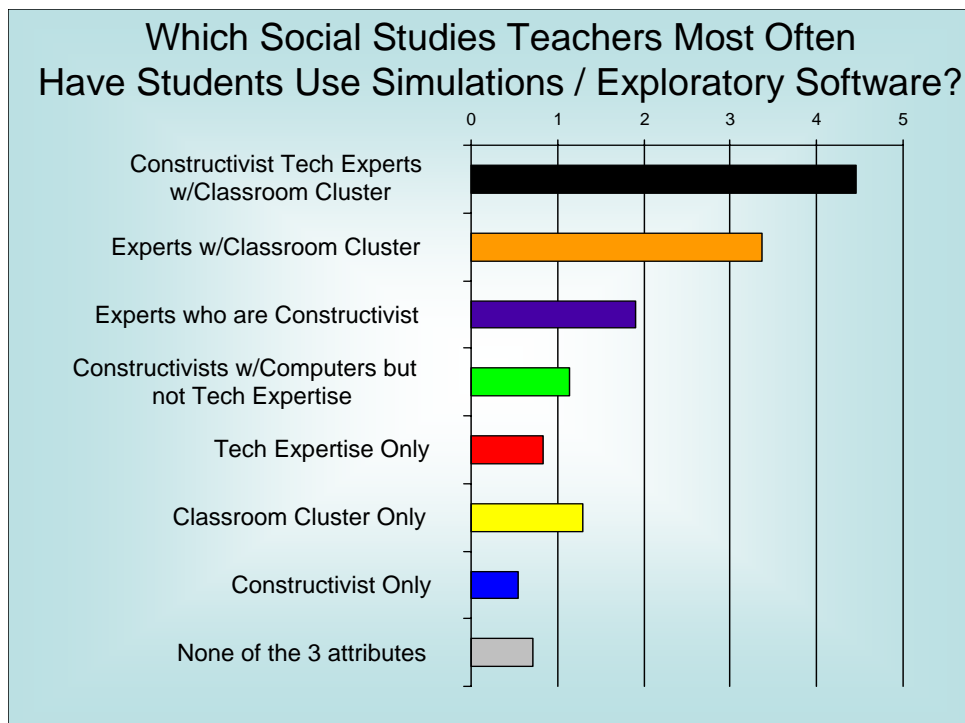
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Applying the model: Technology use, Continued

Beliefs and practices

Teachers' beliefs and practices, quite independent of technology, appear to be related to the objectives for their technology use and the extent of their software use when they do use computers

This graphic shows conditions for computer use by social studies teachers and the amount of use of simulation/exploratory software. Coupled with a classroom cluster of computers and technology expertise, a constructivist-oriented social studies teacher is more likely to use this type of software than others.



Source. Becker, AERA talk, 2002.

Note. Belief and practice measures are available in Ravitz, Becker, and Wong (2000).

The key finding here is that technology expertise among teachers is important to develop, but insufficient by itself for teachers to use software with students.

Applying the model: Technology use, Continued

A cumulative effect

As teaching beliefs and practices are added to the equation and more conditions fall into place it becomes easier and easier to anticipate how one might address error when looking for technology impacts.

One sees a cumulative effect so that the more conditions that are present the more likely it is that there will be a technology impact. Becker summarized the conditions for frequent computer use in a way that is consistent with all of the above findings. Use with students is related to:

- Teacher technical expertise, but also...
- Block schedule helped
- So did not feeling pressured by standardized testing
- The last two were very important:
 - Having a cluster of at least 5 computers in the classroom
 - Having a constructivist teaching philosophy

Source: Becker, H. (2000). Findings from the Teaching, Learning and Computing Survey: Is Larry Cuban Right? *Educational Policy Analysis Archives*, 8(51).

Moving to impacts

Collectively, these studies help us understand better where computers are used and in what ways. Knowing this can help us look more carefully for computer impacts overall and control for possible sources of error.

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Applying the model: Technology impacts

Using the model for impacts

This section turns away from teacher-level data to show how the error model can be applied to school and student achievement related to computer use.

This section makes these points:

- Start with known sources of error, including demographics
 - Location of use has to be thought about very carefully
 - Looking at the bottom line can obscure rather than illuminates
 - It is easier to draw conclusions when you limit the scope of your analysis, but it is important not to avoid more complex questions.
-

Location of use, home and school

In Idaho, it is the larger schools on average that have higher achieving students. What is problematic for technology advocates is that larger schools where higher achieving students attend have worse computer-student ratios and a smaller proportion of students using computers at school.

Achievement, Use, and Income for Idaho Secondary Schools

School size (sports categories)	Overall 2000 school achievement (standardized z-score) within grade	Average number of school computers per 10 students	Average % of students who use computers at school	Average % of students who use computers at home	Median family income (1990) in thousands
< 150	-0.64	4.6	77	67	27.2
150-349	0.02	3.1	79	76	25.7
350-799	0.25	2.0	70	79	27.5
800-1249	0.51	2.1	58	83	31.3
1250+	0.67	1.7	50	85	31.0
All schools	0.00	3.0	73	76	27.2

Source: Idaho study (2002)

If one were not careful, one might conclude that computer use is either unimportant or is negatively related to achievement. At the same time, there is a strong relationship between home use and student achievement at school, probably due to a third variable like parent education level.

While it is true that you can better predict the type of access, use and achievement of students in different size schools, it does not really address the cause of these relationships. To more directly address the impact of school computer use, one might obtain the percent of students that use computers in each school, and then compare their school achievement levels to similar schools.

In our study, we decided to focus on individual students and their software *capability*, i.e., regardless of where this capability was developed and applied. We used software capability as a predictor of achievement rather than use because students who used computers in both locations had higher software capabilities. This was true in high and low income, large and small schools.

Note. We used self-reports of software capability that were administered to students with the ITBS test in Idaho.

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Applying the model: Technology impacts, Continued

Location of use, in school Technology use does not occur in just one place, even *in school*. This creates problems in understanding technology impacts. Looking at subject-specific uses with teachers may make sense in some cases, but not in others.

There are some relationships that are seen among teachers overall and others that are found only for certain subjects. This table shows the percent of teachers using different types of software by grade for all teachers, and for computer teachers only.

Percent of teachers using computers 3 or more times, by grade and subject

	Games for practicing skills		Graphics-oriented programs		Spreadsheet/ Databases	
	8 th	11th	8 th	11th	8 th	11th
Computers-Technology	29	18	17	36	31	52
All teachers	9	4	5	10	5	9

Source: Idaho study. For national report, see TLC'98 Report #3.

It is up to us to decide which uses to include in our analyses, how to think about these uses and what is being accomplished and learned.

In the Idaho study, we analyzed school wide teacher use and use by English teachers only. School-wide teacher use was a better predictor of student achievement gains on reading and language arts tests (Iowa Test of Basic Skills, ITBS) than use by English, reading and language arts teachers alone.

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Applying the model: Technology impacts, Continued

Not just the bottom line

Here is another example that shows how looking at the bottom line alone can be misleading. Across all schools, computer use by math teachers shows no difference in gain scores on math tests. However, if you all split schools into two groups by size, there are relationships, just in the opposite directions.

This would have to be explained by further research, but if technology is actually being used differently in smaller and larger schools by math teachers, this could be a valuable finding.

MATH GAINS BY SCHOOL SIZE AND TECHNOLOGY USE BY MATH TEACHERS IN IDAHO

School size	Computer use by math teachers	N	Within grade, gain score	S.d.
Smaller	Low Tech	26	0.18	0.61
	High Tech	26	-0.21	0.78
	Total	52	-0.02	0.72
Larger	Low Tech	26	0.01	0.41
	High Tech	26	0.26	0.49
	Total	52	0.14	0.47
Total	Low Tech	52	0.09	0.52
	High Tech	52	0.03	0.69
	Total	104	0.06	0.61

Note. This table is based on 8th and 11th grade teachers and the scores of their school's students on the math part of the Iowa Test of Basic Skills (ITBS).. The gain score is based on the standardized residual, the error from trying to predict 2000 scores based on students' 1999 scores alone.

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Applying the model: Technology impacts, Continued

Comparing "with all else equal"

Evidence may show, on average, that higher achieving schools and students use computers more than lower achieving schools and students. What would this really mean? Could one conclude that computers are causing higher achievement or is the relationship spurious?

One way to avoid the bias of a third variable is to only study a subgroup of students, teachers, or schools with similar characteristic and limit your findings to that specific subset. If technology use is associated with student achievement, we will only know to the extent we are able to look at technology impacts, *with other things being equal*. This means we want to identify important other variables (sources of error) and compare students, teachers, or schools have similar characteristics except for their technology use.

Note. Randomization is the most effective way to create "all things equal" conditions. It is rarely used to assign students to different treatments, but randomly selecting schools, teachers, or students to study (not to select for treatment) could remove the effect of some biases.

By showing how the relationship is present or absent given different conditions, one can begin to address the validity of the finding and its generalizability to different populations.

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Applying the model: Technology impacts, Continued

Student level example - hypothetical

Here is one way to use the error model to approach the topic of technology impacts. Imagine you believe the three most important things to consider before drawing any conclusions are

- student prior learning,
- use of computers on their own time, and
- use of computers in class.

If these variables really have a relationship with learning, knowledge of the different conditions would help you understand (and predict) the learning that would occur.

What do you think would happen under any of these conditions? Where would you expect computers to have the greatest impact?

Condition	If initial student achievement is...	and their personal computer use is...	and computer use in class is...	then you expect learning to be...
1	Low	Low	Low	?
2	Low	Low	High	?
3	Low	High	High	?
4	Low	High	Low	?
5	High	Low	Low	?
6	High	Low	High	?
7	High	High	High	?
8	High	High	Low	?

This provides a useful way of thinking about prior achievement and location of use. It is not clear that this design would actually work. It may be too difficult to divide students accurately into low and high performers, and into low and high computer users both in and out of class.

If classroom computer use were associated with better learning outcomes regardless of prior achievement and home use, this would be a remarkable finding.

Note. You have to stop and think about what you expect and what would be a surprise! Chance alone would predict an even distribution of student learning across all eight conditions.

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Applying the model: Technology impacts, Continued

Warnings

Here are some key points to keep in mind:

Failing to take sources of error into account can lead to erroneous conclusions. Judgment and experience play more of a role than is often believed. Researchers and readers of research have to decide if the results are correct, and if so, to whom they apply. Statistics cannot compensate for a poorly designed study, and they cannot tell you if the finding is important (Katzer, 1998).

Averages for groups do not reflect on individuals. Even if certain subgroups perform lower than others, there is still often a full range of performance within those subgroups. One should not draw conclusions from group averages via stereotyping when judging individuals, or generalize from experiences with individuals to others of the same group, (Popham, 2002).

Conclusion

This paper sought to help educators by

- Providing an accessible but research-proven way to address technology impacts
- Examples of key issues to consider and ways to avoid error based on research

It also wants to offer a forum for discussing these issues further.

Invitation to discuss

Invitation to discuss!

Audience members are encouraged to discuss this paper and how it applies to their own planning efforts. An online discussion forum will be set up for further discussion of these issues, if enough people are interested.

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Please let me know your reaction to this paper. Thank you!

Buck Institute for Education (BIE) and me

The Buck Institute for Education (BIE) is a non-profit research and development center for problem based learning, based in Novato, CA.

BIE Homepage: www.bie.org

Dedication

This paper is dedicated to the memory of Professor Jeffrey Katzer (1941-2000) of the School of Information Studies at Syracuse University. He taught several generations of students (including mine) to think more critically about research using this approach.

See the following for more information:

Katzer, J. (1981). Understanding the Research Process: An Analysis of Error. In Charles H. Busha (Ed.). *A Library Science Research Reader and Bibliographic Guide*. Littleton, CO: Libraries Unlimited 1981. 51-71.

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Teaching, Learning & Computing: 98

<http://www.crito.uci.edu/TLC/html/findings.html>

Idaho Study: Technology Initiative Evaluation

<http://web1.twt.jkaf.org/index.html>