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ABSTRACT

This paper summarizes formative evaluation activities during the development of a pilot program by the Consortium for Mathematics and Its Applications for a telecourse on introductory data analysis. These activities included: (1) two major design activities--selection of a statistician host teacher and script development; (2) production phase activities--testing of the rough-cut pilot with students and statistics faculty in order to assess the appeal, comprehensibility, and recall of the materials; and (3) implementation activities--viewing of the pilot unit by students in statistics classes across the country, who also read the associated textbook materials and did the appropriate homework exercises. (The formative evaluation plan for the rough-cut pilot has been replicated for the final version of the television program.) Pretest-posttest performance by 300 students demonstrated a significant increase in achievement of the learning objectives. Included are six figures showing evaluation questions, findings, and actions taken for the three phases as well as data on recall, appeal, and comprehensibility. (MES)

Formative Evaluation in the Development Phases of a College Telecourse

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Paper presented at the meeting of the American Evaluation Association, Boston, MA, October, 1987

Introduction

The Consortium for Mathematics and Its Applications (COMAP) is developing a telecourse for college students on introductory statistics. The development is sponsored by the Annenberg/Corporation for Public Broadcasting Project.

A telecourse is a college credit semester course that has a textbook and homework assignments but uses television in place of the lectures. Students who sign up with their local college as distant learners will do their work at home and meet occasionally with a professor on campus.

Over the past six months the COMAP project team has developed a pilot learning unit consisting of one half-hour television program and associated textbook and homework materials. This presentation will summarize the formative evaluation activities during the design, production, and implementation phases of the pilot program for the statistics telecourse.

Learning Unit Effectiveness

I would like to begin by telling the end of the story first. Two weeks ago, 300 students in Introductory Statistics courses across the country viewed the pilot television program, read the textbook material and did the homework assignment. The pilot learning unit discussed linear and exponential models for growth.

When pretest performance was compared with posttest performance on criterion-referenced questions, students demonstrated a significant increase in achievement of the learning objectives ($p < .01$). Thus, the one-group pretest-posttest evaluation gave evidence as to the instructional effectiveness of the pilot learning unit.

Leading up to this successful ending has been six months of formative evaluation activities during the design and production phases of the pilot television program. The production staff used information from each formative study to improve the potential effectiveness of the program materials.

Design Phase and Pre-production Formative Evaluation

During the Design Phase, there were two major pre-production formative evaluation activities. One effort involved the choice of a program host, while the second concerned script development.

Host teacher studies. Because the proposed format of the television program called for a statistician host teacher, one of the first decisions of the Design Phase was who to choose for the host teacher.

Insert Figure 1 about here

The goals of the pre-production formative evaluation, therefore, were to determine the appeal of a variety of host teachers and to explore what qualities supported or detracted from that appeal. Not only did the producers desire students' feedback as to which host teacher to choose but they also wanted information that would help them direct the host teacher in the pilot production.

Two host teacher studies were carried out with a total of 95 students from two- and four-year institutions in Boston. The students viewed viceotapes of auditions of local statisticians. Each host teacher candidate read a short piece of script and then using provided props presented an extemporaneous lesson on the making of and meaning of an histogram.

After viewing each host teacher, students gave a one word description of their immediate feeling about the candidate and then rated the candidate's appeal, enthusiasm, approachability, and confidence. S[illegible]ts also comparatively ranked the candidates and provided reasons for their first choice host teacher.

Participating students expressed a wide diversity of opinions about who was the best host teacher. The data analysis pointed to three characteristics which appeared to determine students' choices: an approachable personal manner; an attractive physical appearance, and a pleasant voice quality. However, an approachable personal manner was found to detract from appeal when it was too casual or "laid-back."

Although none of the candidates won a clear majority of first choice votes, one statistician (let's call her Teresa) did appeal consistently across the whole range of students. Teresa received high scores on all the rated characteristics and received the majority of positive student comments with very few negative comments. She was portrayed by students as "very warm and pleasant" with a "good speaking voice" and a "clear and understandable" presentation.

None of the auditioning statisticians turned out to be the charismatic television personality for whom the producers were looking. However, the formative evaluation data confirmed the producers' intuitions that Teresa was "a pleaser who would provoke very little negative reaction." The diversity of the telecourse target audience required someone with mass audience appeal; so Teresa was asked to host the television series.

<u>Script development</u>. Another activity of the Design Phase was to develop an effective pilot script.

Insert Figure 2 about here

The goals of the pre-production formative evaluation at this time were to obtain feedback as to the clarity, accuracy, and comprehensiveness of the content and to assess the strengths and weaknesses of the program's instructional format. The format of the program involved documentaries and animated graphics that demonstrated the application of statistical concepts to real-life problems. The format also used a host statistician who introduced, elaborated, and summarized the statistical concepts.

This past June, a draft pilot script was reviewed by five Statistics professors from a variety of institutions and states. There was astonishing agreement among the reviewers about what was strong and what was weak in the script, as well as about specific changes. The general strengths applauded by the reviewers included the examples chosen for the documentaries and the level of explanation in the script. The weaknesses identified included statistical inaccuracies and terminology problems, as well as a feeling that the human interest aspects of the documentary examples were given precedence over the statistical points. Moreover, the statisticians believed that the content objectives were not obvious.

In response to the expert review study, the production staff rewrote the script, correcting inaccuracies and tightening terminology. The content objectives were more clearly defined in the introductory and concluding segments. In the documentary segments, the narrator's explanation of statistical concepts was expanded. And finally, the amount of material which was entertaining but irrelevant to the statistical points was decreased. The production staff's goal in making these changes was to achieve a balance between the educational objectives and the motivating audiovisual quality of television.

Production Phase and Production Formative Evaluation

Once the script was reworked to reflect the feedback of the subject matter experts, the project team moved into a production phase.

Insert Figure 3 about here

Initial efforts focused on producing an unpolished videotape version of the first half of the revised script.

The topic was the linear model of growth. The rough cut program began with a brief overview by a female host (Teresa was not available at this time). Two documentaries followed describing the use of growth curves to assess the need for growth hormone therapy in slow growing children. Finally, the host introduced concepts including the least squares line, the pattern of residuals, and prediction.

Rough cut study. The rough cut pilot was tested with the target student audience and statistics faculty to provide feedback to the production staff about their format decisions. The major goals of the production formative evaluation were to assess the appeal and comprehensibility of program segments as well as to measure student short-term recall.

An 18 minute videotape was shown to 53 students in Introductory Statistics classes in 3 states.

Insert Figure 4 about here

Student recall of the program content was measured with four recall questions. These questions were answered by a random half of the students prior to viewing and by all of the students after viewing. Viewing the program resulted in a significant increase ($p < .01$) in knowledge on three out of the four questions.

In addition to measuring recall outcomes, the formative evaluation attempted to analyze what was appealing and understandable in the program and what was not.

Insert Figure 5 about here

To this end, a continuous reaction measure was employed. While viewing the rough cut program, half of the students rated the appeal of the material at 7 different points. The other half of the students rated the comprehensibility of the material at the same 7 points. Students were randomly assigned to rate either appeal or comprehensibility. The researcher called out the numbers 1-7 to indicate when students were to rate the material while the videotape continued running.

Students rated the majority of the program as understandable but appeal remained high only during the documentary segments, dropping off when the host teacher explained some additional statistical concepts.

In addition to the continuous reaction measure, student response was elicited about the program pace, the style of graphics, what parts they liked most and least, and what concepts they felt needed more explanation (see Figure 3). Generally, students rated the pace of statistical concepts as too fast and were only midly positive about the informal graphic style used in the program.

Ratings on the continuous reaction measures, posttest recall results, and student and faculty responses to postviewing questions complement each other to give the project team a picture of what works in the program, what doesn't work, and possible reasons why. For example, the continuous reaction measure showed a dip in comprehensibility and appeal at point #6 (see Figure 5). At this point in the program, the host teacher is narrating a series of graphic displays about the pattern of residuals or deviations from the least squares line. The pretest results showed that this was a new concept to the students, and the posttest results indicated a significant improvement in understanding this concept, but only 42% of the sample gave the correct posttest answer (see Figure 4). When asked what topics in the program needed further explanation, 52% of the viewers wanted more about the pattern of residuals. The students did not feel confident of their knowledge of this concept. Repeated confirmation of a difficulty in the program through differing measuring instruments can convince producers that serious revision is necessary; just adding a music track won't work. Inductive analysis of the complementary data sets provided the production staff with information on which to base revisions in the television program format.

The production staff concluded that the documentaries could handle more graphics and discussion about the statistical objectives without sacrificing audience interest and understanding (see Figure 3). They decided to decrease the host on-air exposure, while carrying one or more of the content objectives with narrated graphics. Further, each program would be limited to 5-7 content objectives in order to treat them in more depth at a slower pace. Finally, the graphic style would change to a slicker commercial television look.

Implementation Phase and Implementation Formative Evaluation

We are currently analyzing data from the final pilot phase, that is, from the implementation of the pilot learning unit in the classroom (see Figure 6).

Insert Figure 6 about here

The formative evaluation plan for the rough cut pilot has been replicated for the final televisi program. Additionally, the complete learning unit was implemented in statistics classrooms in 4 states. The goals of this formative evaluation are to detemine whether students achieve the learning objectives, how confident they feel about their knowledge, and how they feel about the curriculum components separately and together.

As with the previous studies described, the implementation formative evaluation allows the student and faculty users to have a voice in the design of the statistics telecourse. The producers will consider the feedback from students and faculty about the strengths and weaknesses of the pilot learning unit when developing plans for the next 25 statistics telecourse units.

In summary, formative evaluation has played a critical role in helping to guide the design and revisions of the pilot learning unit of COMAP's statistics telecourse.

Figure 1

DESIGN PHASE ACTIVITY: HOST TEACHER CHOICE

PRE-PRODUCTION FORMATIVE EVALUATION:

EVALUATION QUESTIONS

WHICH HOST-TEACHER DO STUDENTS FIND APPEALING?

WHAT QUALITIES SUPPORT OR DETRACT FROM APPEAL?

FINDINGS

QUALITIES SUPPORTING APPEAL:	APPROACHABLE PERSONAL MANNER
	ATTRACTIVE PHYSICAL APPEARANCE
	PLEASANT VOICE QUALITY
QUALITIES DETRACTING FROM APPEAL:	CASUAL/LAID-BACK PERSONAL MANNER

ACTION TAKEN

"TERESA" CHOSEN AS HOST

Figure 2

DESIGN PHASE: PILOT SCRIPT DEVELOPMENT

PRE-PRODUCTION FORMATIVE EVALUATION:

EVALUATION QUESTIONS

IS THE SCRIPT CLEAR? ACCURATE? COMPREHENSIVE?

WHAT ARE THE PROGRAM FORMAT'S STRENGTHS AND WEAKNESSES?

FINDINGS

STRENGTHS: GOOD EXAMPLES FOR DOCUMENTARIES

APPROPRIATE LEVEL OF EXPLANATION

WEAKNESSES: STATISTICAL INACCURACIES

LOOSE USE OF TERMINOLOGY

HUMAN INTEREST ASPECTS OF DOCUMENTARIES GIVEN PRECEDENCE OVER STATISTICAL POINTS

CONTENT OBJECTIVES UNCLEAR

ACTION TAKEN

CORRECTION OF INACCURACIES AND TERMINOLOGY

CLEARER OPENING AND CLOSING STATEMENTS OF CONTENT OBJECTIVES

INCREASE IN AMOUNT OF EXPLANATION OF STATISTICAL CONCEPTS BY NARRATOR IN DOCUMENTARIES

DECREASE IN AMOUNT OF ENTERTAINING BUT CONTENT-IRRELEVANT MATERIAL

Figure 3

PRODUCTION PHASE: ROUGH CUT PILOT

PRODUCTION FORMATIVE EVALUATION:

EVALUATION QUESTIONS

WHAT PARTS DID STUDENTS FIND APPEALING?

WHAT PARTS DID STUDENTS FIND COMPREHENSIBLE?

DID STUDENTS RECALL PROGRAM CONTENT?

FINDINGS

SIGNIFICANT IMPROVEMENT ON 3 OUT OF 4 CONTENT QUESTIONS

DOCUMENTARIES APPEALING AND UNDERSTANDABLE

HOST TEACHER SEGMENTS LESS APPEALING AND LESS UNDERSTANDABLE

PACE OF STATISTICAL CONCEPTS TOO FAST

GRAPHIC STYLE MILDLY APPEALING

ACTION TAKEN

INCREASE GRAPHICS AND DISCUSSION ABOUT STATISTICAL OBJECTIVES IN DOCUMENTARIES

DECREASE HOST ON-AIR TIME

USE NARRATED GRAPHICS TO CONVEY ONE (OR MORE) OF OBJECTIVES

LIMIT EACH PROGRAM TO 5-7 CONTENT OBJECTIVES

INCREASE DYNAMICS AND PROFESSIONAL TV LOOK OF GRAPHICS

Figure 4

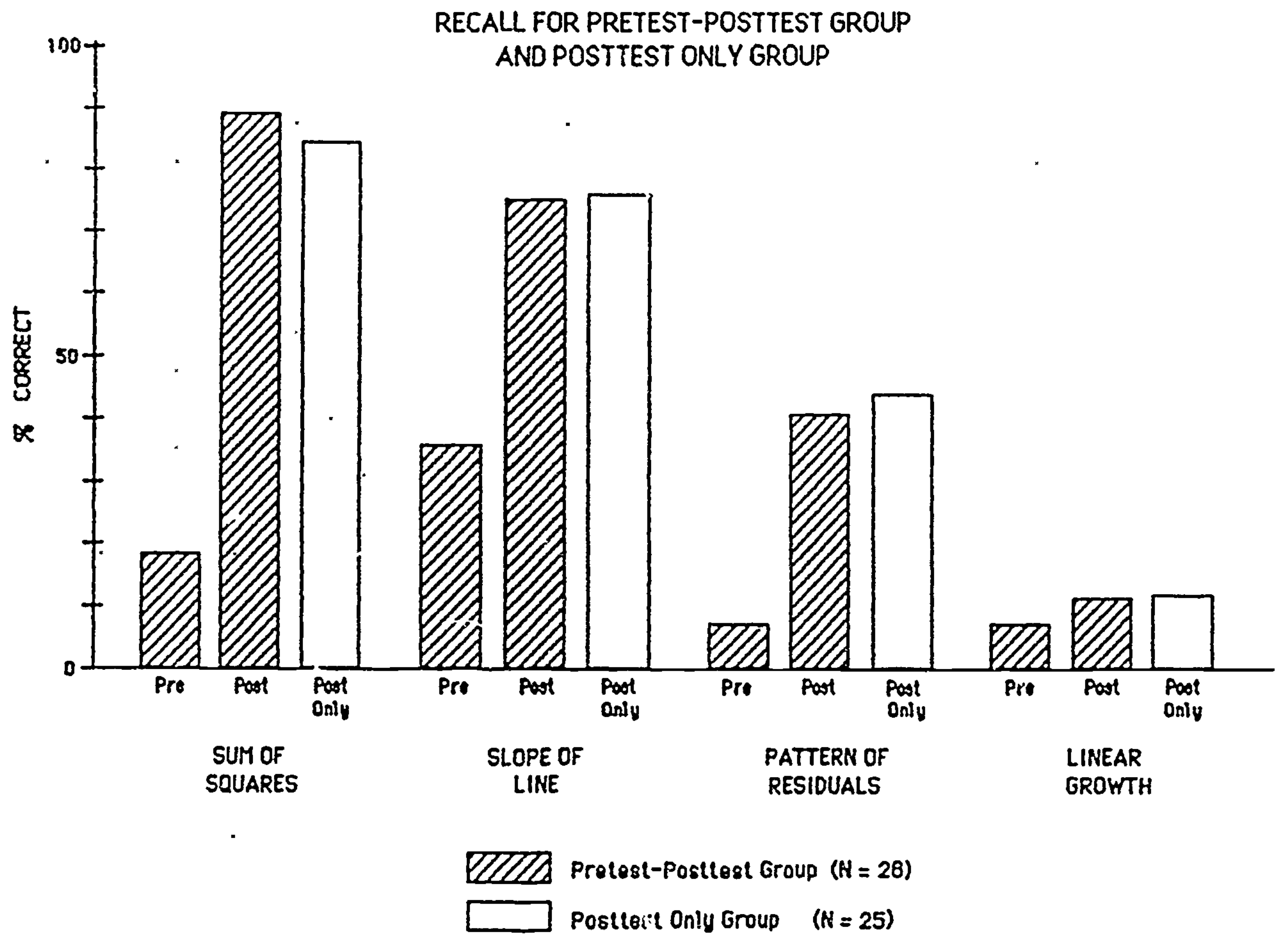
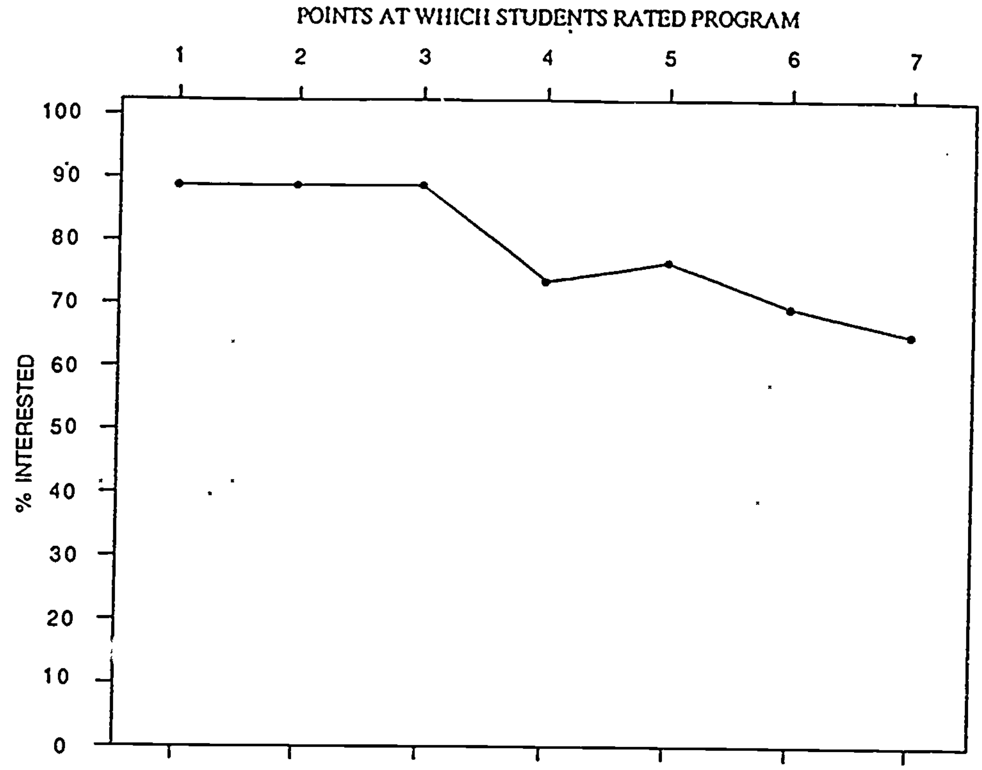

RECALL FOR PRETEST-POSTTEST GROUP
AND POSTTEST ONLY GROUP
100
50
0
% CORRECT
Pre
Post
Post Only
Pre
Post
Post Only
Pre
Post
Post Only
Pre
Post
Post Only
SUM OF SQUARES
SLOPE OF LINE
PATTERN OF RESIDUALS
LINEAR GROWTH
Pretest-Posttest Group (N = 28)
Posttest Only Group (N = 25)

Figure 5

APPEAL RATINGS (N = 26)



COMPREHENSIBILITY RATINGS (N = 27)

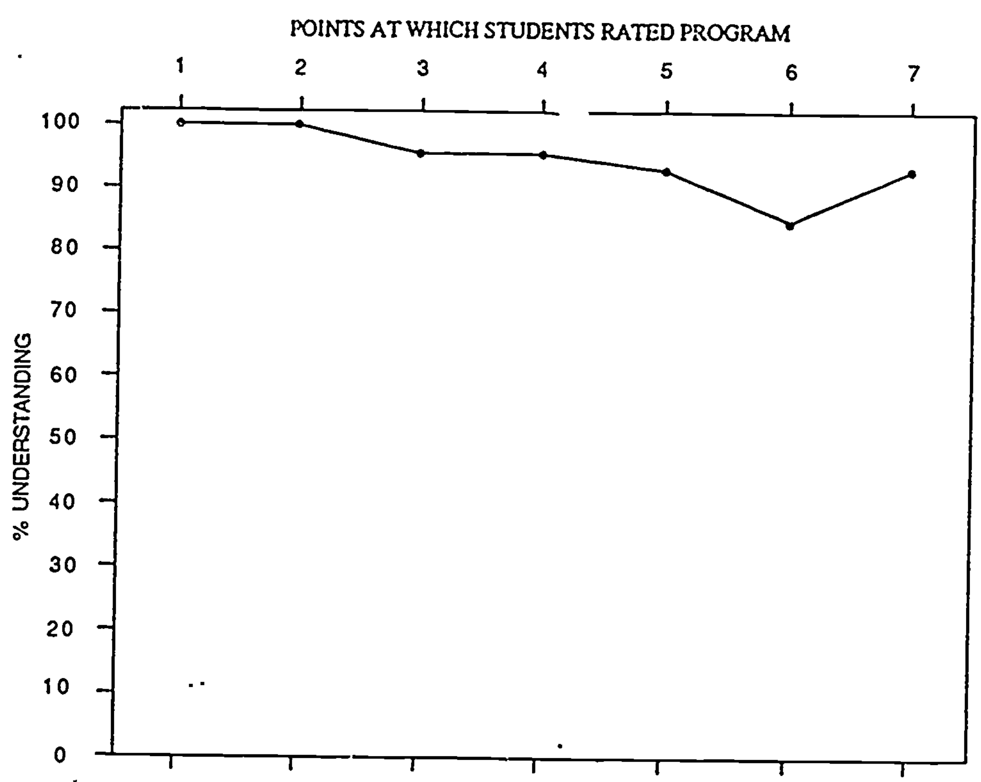


Figure 6

IMPLEMENTATION PHASE: PILOT LEARNING UNIT COMPRISES HALF-HOUR TELEVISION PROGRAM AND TEXTBOOK WITH HOMEWORK

IMPLEMENTATION FORMATIVE EVALUATION:

<u>EVALUATION QUESTIONS FOR TV PROGRAM</u>

WHAT PARTS DID STUDENTS FIND APPEALING?

WHAT PARTS DID STUDENTS FIND COMPREHENSIBLE?

DID STUDENTS RECALL PROGRAM CONTENT?

<u>EVALUATION QUESTIONS FOR LEARNING UNIT</u>

DID STUDENTS ACHIEVE THE LEARNING OBJECTIVES?

HOW CONFIDENT DID STUDENTS FEEL ABOUT THEIR KNOWLEDGE?

HOW DID STUDENTS RATE THE TV PROGRAM, TEXT, AND EXERCISES SEPARATELY ON DIFFICULTY, CLARITY, COMPLETENESS, HELPFULNESS, AND APPEAL?

HOW DID STUDENTS RATE THE UNIT AS A WHOLE?

sample than it does for the males, with a generalized multiple correlation coefficient of $R^2 = .405$. Although only 40.5% of the joint variation in the set of endogenous or dependent variables is explained by the full model for females, this proportion is still significantly different from 0, W = 1166.16, evaluated as chi square with 20 degrees of freedom. The path coefficients for females are similar to those of the males, but with some notable exceptions. Having a home computer is more positively predictive of acquiring some level of computer competency for males (.442) than it is for females (.336), and is also more predictive of frequency of recreational usage of computers for males (.376) than it is for females (.224). Also, computer competency is more likely to be associated with higher levels of self-confidence with regard to recreational computer use for males (.222) than for females (.157). These differences in path coefficients are significant, $z = 4.97$, $\underline{p} < .001$, for the first and second differences, and $z = 1.69$, $\underline{p} < .05$, one-tailed, for the comparison between the relationship between computer competency and self-confidence in recreational computer use.

Reduced models for prediction of male and female recreational computer usage. Although the fully recursive model shown in Figure 2 can be supported as a logical basis for predicting recreational computer use, it is also reasonable to predict that some of the paths in the model are of less potency than others for males while different paths may be reduced or enhanced in potency for females. Figures 3 and 4 show the predicted reduced models for prediction of males' and females' recreational computer usage. Labels of W, M, and S appear on the paths to express the hypothesized relative weights of the retained paths with regard to prediction (W = weak, M = moderate, S = strong). A number of paths have been deleted from the full model; these paths are hypothesized to have little effect on prediction when other variables are retained.

Insert Figures 3 and 4 about here

There are a number of differences in the hypothesized male and female models. A major difference is the exclusion of the computer competence variable from the male model. It is predicted that recreational usage of computers is so strongly pictured as "a thing males do" in the adolescent culture that a male student feels he can be an effective game player even if he has little computer competence or experience. Another major difference in the models is that the female model represents a more complicated set of influences preceding the female's decision to use a computer for recreation. It is hypothesized that the female will be more influenced by her perception of her parents' attitudes about herself as a recreational computer user and will also be more sensitive to the impact of male-oriented stereotypes on her own self-confidence level than an adolescent male may be. It is further hypothesized that the female is more likely to want to feel computer competent before she risks computer usage for fun, and that her pleasure associated with recreational usage will be strongly influenced by her perceived competence and confidence. Males, it is hypothesized, do not particularly need this type of affective reinforcement, but find the process of recreational computer use much more straightforward; in fact, almost something expected of an adolescent male.

Testing the reduced models. In order for the reduced models to be supported as providing a reasonable fit for the data, male and female data were subjected to a series of regression analyses based on the gender-specific models. Beta coefficients and multiple R^2 values from these analyses were used in a subsequent series of path-analytic procedures. In addition, the fit of each gender-specific model for students for which it was intended was compared to the fit of the same model for students of the opposite gender, again using path-analytic procedures, to investigate the hypothesis that the gender-specific models reflect gender differences in systems of predictors of recreational computer use.

The specific hypotheses tested include:

1. The male model can be supported as providing a reasonably close fit for the fully recursive model for males.

2. The female model can be supported as providing a reasonably close fit for the fully recursive model for females.

3. The male model will fit the male data better than it fits the female data.

4. The female model will fit the female data better than it fits the male data.

And in summary,

5. Gender differences in the frequency of recreational computer usage are predicted by the differences in the male and female models.

Specht's test will be used to assess the fit of each pair of models.

Test of male and female reduced models for prediction of recreational usage. Figures 3 and 4 show the path coefficients for the male sample on the reduced male model and for the female sample on the reduced female model. In addition, path coefficients for the female data on the reduced male model and for the male data on the reduced female model are shown in parentheses. The residuals for the recreational access variable are .755 for male data on the male model, .843 for female data on the male model, .756 for female data on the female model, and .844 for male data on the female model.

The path coefficients show five of the hypothesized paths in the male model are indeed associated with prediction in the model. The prediction that males' stereotypic perceptions of computer games being male-appropriate would only weakly influence males' actual recreational usage is supported. All three path coefficients emerging from the stereotype variable are small and contribute little to the prediction of other variables in the system. Parents' educational level influences recreational computer use less than what was predicted in the male model and stereotypes had a weaker impact on self-confidence for males than was predicted.

In order to assess the goodness of fit of the male model for males compared to the full recreational model, the Q statistic, $\frac{1 - R^2\text{Full}}{1 - R^2\text{Model}}$, was calculated and found to be equal to .673 (Specht, 1975). Q can vary between .000, showing no correspondence, or fit, in two models, to .999, showing the near-equivalence of two models. A Q of .673 shows a reasonable match when the more parsimonious male model is compared to the full recreational model. This goodness of fit can be evaluated for statistical significance; however the large sample size in this study jeopardizes the possibility of retaining a model (Anderson, 1987) even with a Q as high as .99. Because of this sensitivity to sample size, x^2 is not recommended as a significance test for large models and samples such as these.

Another approach can be used to test the value of the male model as a predictor of frequency of recreational computer use for males: The model can be run using the female sample data and a Q value calculated to compare the fit of the male model for males and for females. The ratio obtained for this Q is $\frac{.615}{.722}$ or .852. The reduced male model explains 1 - .615 or 38.5% of the joint variation in the males' sample data, as compared to 1 - .722 or 27.8% of the joint variation in the females' sample data, and thus is a better fit for prediction of males' recreational computer usage than it is of females'.

The female model was evaluated in a similar manner as was the male model for predicting recreational computer usage. All but two of the paths hypothesized to be valuable as predictors of females' recreational computer usage are refelected in the moderately strong path coefficients for female data on the reduced female model. As was the case in the reduced male model, competency is a more important predictor of self-confidence for females than had been expected, and stereotypes were considerably less involved in the prediction of other variables in the system than had been predicted. Finally, perceived competency affects self-confidence more than had been predicted for females.

A comparison of the fit, for females, of the female model with the full recreational model yielded a Q of $\frac{.595}{.648}$, or .918, indicating a very good fit of the more parsimonious recreation model for females. However, a comparison of the fit of the female model for females to its fit for males gives an unexpected result. The female model explains only 35% of the joint variation in the recreational usage system for females, but explains 52.5% of the joint variation for males. It is clear that alternate formations of the male model for predicting recreational computer usage should be considered.

Predicting Use of Home Computers for Nonrecreational Purposes

Certainly students are very familiar with recreational usage of computers. It is reasonably easy for most students to have some interaction with computer games, as game machines now are ubiquitous components of corner stores, ferries, and computer arcades. Games frequently are quick and easy to play, at least in a casual manner, so it was reasonable to assume in the models used to predict recreational access to computers that having a home computer was not essential for access to occur. However, a second category of computer use--nonrecreational home use--cannot be assumed to be realistically available for students without any access to a home computer. The type of tasks associated with this category require time and often repeated periods of time. It is unlikely that many students routinely do word processing at a friend's house, for example, in the way they might casually play a game. Therefore, the full model we present for predicting use of a computer for nonrecreational home task purposes will only pertain to students with a computer in their homes. Examples of uses of a home computer for nonrecreational purposes include word processing, printing "something like posters, invitations, cards," "trying to learn something on a computer at home that is not part of homework," and doing homework. Homework is included as schools cannot yet require students to do homework at home on a computer because of the obvious difficulties this would create for the many students without home computers. Thus it can be assumed that use of a home computer to do homework is largely a voluntary decision by the student because presumably even computer science assignments could be done at school if the student really did not wish to make use of a home computer. Therefore, a variable expressed as a weighted combination of frequency of home usage in the above categories of uses was calculated for all students having home computers. This variable could range between 0 and 12 educational levels to make use of computers for task-type purposes in their offices or for "productivity tasks" at home. Therefore the model assumes that parents' educational level will have an influence on student task usage even when the sample already reflects the influence of parents' educational level by only including students with home computers. A variable reflecting parents' educational level was calculated in the same way as it was for the recreational models.

Nonrecreational task-type computer usage typically will involve reading of manuals and may involve considerable effort and persistence. Commercial productivity-oriented programs are not as simple to use as games may be and frequently require the user to be tolerant of and successful with self-directed efforts. Therefore it is reasonable to predict that a student's academic ability may predict his or her tendency to make voluntary use of home computers for nonrecreational usages since the same components of persistence, reading ability, and self-direction may also underlie academic success at school. Therefore, a variable relating to academic ability that requested the students to rate their grades compared to those of their classmates was included as one of the exogenous variables in the model. Although it is likely to be correlated with parents' educational level, for purposes of this model it is only assumed to be correlated with, and was the criterion variable for the next set of models.

<u>Exogenous variables in the full model for prediction of home nonrecreational computer usage</u>. It is reasonable to predict that parents' educational level will be associated with student use of a home computer for nonrecreational purposes. Parents with higher educational levels may be more likely than parents with lower educational levels to make use of computers for task-type purposes in their offices or for "productivity tasks" at home. Therefore the model assumes that parents' educational level will have an influence on student task usage even when the sample already reflects the influence of parents' educational level by only including students with home computers. A variable reflecting parents' educational level was calculated in the same way as it was for the recreational models.

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The stereotypes a student endorses about computer use and computer users are also hypothesized as exogenous variables in the full model to predict students' home nonrecreational use. If students perceive home nonrecreational use to be gender-typed or associate it with unattractive personality stereotypes they are less likely to choose to be identified with the usage themselves. Therefore, a variable was created as a weighted sum of responses to six statements on the survey instrument reflecting stereotypes about social, intellectual, and gender-related stereotypes about computer users. Each variable was recoded so that the higher the score on this variable the less stereotyped were the student's responses. This stereotype variable could range from 0 to 20.

Endogenous variables associated with the prediction of nonrecreational use of home computers. It is reasonable to predict that taking a computer-related course in school would expose the student to a variety of computer applications so that he or she would be more likely to use a home computer for similar activities or to do homework associated with the course. Therefore a variable, coded 0 if the student had not taken a computer course and 1 if he or she had, appears as a predictor of nonrecreational use of a home computer in the model. This computer course variable is classified as an endogenous variable in the model because of the assumption that parents' educational level, student's own academic performance, and stereotypes the student has about computer users will all influence the decision to take a computer course. Academic ability is included because the majority of computer science courses in secondary school require mathematics facility as a prerequisite and are typically perceived as challenging courses by students and teachers. Similarly it is reasonable to presume that the more "computer literate" the student is, the more likely the student will use a home computer for nonrecreational purposes.

A variable to represent computer competency was calculated in a similar way as occurred in the recreational model, with the addition of information from an item that directly assesses the student's perception of his or her competency with nonrecreational home uses. The competency variable ranges from 0 to 12 and is assumed to be influenced by the student's having taken or not taken a computer course in school, and also by the exogenous variables in the model. Computer course experience and level of computer competency are also assumed to influence the student's perception of the value of doing tasks with a home computer; therefore an item from the survey instrument asking the student to describe his or her use of a home computer for tasks by selecting a point on a five-point scale with endpoints "Wasting time" and "Using time well" is included in the model. It is assumed that a student is more likely to use a home computer for nonrecreational purposes if the usage is perceived as valuable rather than frivolous (whereas the latter may well be the case with recreational usage). Again, the exogenous variables are also assumed to have an influence on the perception of the value of nonrecreational computer usage.

Finally, it is reasonable to assume that self-confidence and a general sense of enjoyment will influence a student's decision to use a home computer for nonrecreational purposes, although the enjoyment factor is likely to be considerably less salient than it is for recreational use. Self-confidence is assumed to precede "general liking" in the model. Figure 5 shows the full recursive model for home nonrecreational use. For clarity, paths are not shown in the model; however they can be assumed to associate every variable as a predictor of every other variable located to the right of it in the diagram.

Insert Figure 5 about here

Goodness of fit of full model for nonrecreational home usage. Using the responses from the 583 males with home computers in the sample, multiple regression and path analysis were used to assess the fit of the full model for males. The model fits the male data well, with a generalized multiple regression coefficient of .874. Exactly the same generalized multiple regression coefficient was obtained with the data from the 417 female students with home computers. The specific prediction of nonrecreational home usage is slightly better for female students than for male students, with 33.1% of the variability in nonrecreational home usage explained for females compared to 32.1% explained for males.

Although the overall fit of the model is the same for females and males, the prediction equations developed from the direct and indirect effects in the models show gender differences in the patterns of strength of the predictors. (Coefficients can be directly compared within each equation because they are standardized beta weights.) Table 2 compares the coefficients within each prediction equation.

Insert Table 2 about here

For both males and females level of computer competency is the strongest predictor of nonrecreational home usage of computers, followed by self-confidence and liking for male students and the same two variables in reversed order for female students. Stereotypes about computer users is the fourth strongest predictor for females, but only the seventh for males. For both males and females, academic performance was in fifth position, perceived value of the computer application in sixth place, and parents' educational level in last place. For females, surprisingly, parents' educational level has an inverse relationship to frequency of home nonrecreational use of computers. Thus other than the stronger relative importance of stereotypes on home use for females and the stronger relative importance of computer course experience for males the path coefficients in the two equations show very similar patterns.

Further inspection of path coefficients for the five equations defining the other endogenous variables in the models shows the same patterns of relative impact. Parents' educational level has little predictive relationship with any of the endogenous variables while computer competency, self-confidence, and liking display a strong relationship in every equation in which they play a part. For males, the strongest individual predictors in the overall model are computer competency as a predictor of self-confidence (.600) and of frequency of home usage (.520), and self-confidence as a predictor of liking (.543). The same three pairs of associations show up most strongly for females, with path coefficients of .480, .483, and .541, respectively.

Reduced model to predict male's nonrecreational home use of computers. The full model for predicting nonrecreational home use of computers used eight variables as predictors. It is desirable that more parsimonious subsets of this model can be hypothesized so that they still provide good fits for the male and female data but at the same time might better highlight gender differences in the variables that influence nonrecreational home use for students having access to home computers. A rationale of the proposed reduced male model follows.

There is reason to predict that males' frequency of nonrecreational home computer use may be largely influenced by three sources: parents' educational level, perceived utility of the computer application, and general liking or disliking of using a computer for nonrecreational purposes. Furthermore, it may be reasonable to predict that the other five variables in the model contribute only indirectly to the final prediction of usage for males through their influence on the three variables which directly influence the prediction. Academic ability, for example, will likely remain related to parents' educational level, stereotypes about computer users, and decision to take a computer course in school, but it is possible that, beyond this, males' sense of self-confidence, degree of computer competency, and of liking of nonrecreational computer use, as well as their level of perceived value of computer use, do not directly reflect academic achievement level. Figure 6 displays the reduced model for predicting nonrecreational home usage of computers for males, the hypothesized relative relevance of the retained paths, and the obtained path coefficients for the model when tested first with the male data and then with the female data.

Insert Figure 6 about here

Fit of the reduced male model for male and female students. The reduced male model explains 82% of the variability in frequency of nonrecreational home computer usage for males who have access to home computers. In comparison, the full model explained 87.4% of the variability in males' usage. The comparison of these two proportions yields a Q value of .700, which suggests the reduced male model, with 18 fewer paths than the full model, does a reasonable job of fitting the data and also can facilitate interpretation, since so many fewer paths are involved.

Another way to assess the validity of the reduced male model is to compare its fit with the female data to its fit with the male data. Although the full models fit the male and female data equally well, Figure 6 revealed gender differences in the relative weights of path coefficients with regard to stereotypes and the effects of computer courses. As the reduced male model was developed specifically to reflect influences on males' nonrecreational home usage of computers, it is reasonable to expect it to fit the male data better than it fits the female data. However, this was not the case, as the male model predicted 81.9% of the variability in females' use of home computers for nonrecreational purposes (compared to 82% of the variability in males' usage).

When direct and indirect effects are combined, the equations generated for males and females on the male model are very similar, both in pattern and size. In each case, liking is the strongest predictor of nonrecreational home use. In addition, relatively strong indirect effects were obtained for self-confidence (.355 and .352) and computer competence (.279 and .260) as predictors of nonrecreational home use even though direct effects for these variables as predictors of nonrecreational home use were not included in the male model. Perceived value of the computer use, which was hypothesized as being an important predictor in the reduced male model, did not emerge as having a strong predictive value. In addition, parents' educational level was not a predictor of nonrecreational home use.

Reduced model to predict females' nonrecreational uses of home computers. While it was predicted that the frequency of males' nonrecreational use of home computers would be a relatively straightforward reflection of how attractive and useful they perceive a computer application to be, it is reasonable to predict that for females the decision to use the computer may be influenced in a more complicated fashion. In particular, it is likely that females are more influenced by the stereotypes they hold about computer users and by their own levels of self-confidence than they are by more objective variables such as previous computer experience and perceived value of the computer application. As females are significantly less confident about themselves as computer users than are males, and as many of the stereotypes both males and females endorse imply that computer users are males with somewhat unattractive personalities, the impact of these variables in the model may contribute strongly to females' levels of use of nonrecreational computer applications. The female subset of the full predictive model is given in Figure 7 along with the hypothesized relative strengths of the retained paths for females and the path coefficients obtained by testing the model with first the female, then the male data.

Insert Figure 7 about here

Fit of the female model for females compared to males. Using path analysis, the female model was found to explain 85.7% of the variance in females' frequency of nonrecreational uses of home computers. This compares to the 87.4% explained by the full model for females and shows that the reduced model with 13 fewer paths provides a very good fit for the female data, Q = .881. When the male data were tested against the female model, the female model explained 86.1% of the variability in males' nonrecreational home usage. Thus the female model fits the male data even better than it fits the female data, and in addition fits the male data better than did the male model. The path coefficients for the female model for both males and females were shown in Figure 7.

As before, a number of the predictions concerning the relative strength of predictors in the reduced female model were not supported by the female data. Parents' educational level had only a weak influence on computer competency and perceived value of computers for females; the relationship was predicted to be a moderate one. Academic ability was predicted to be a strong component of computer course attendance; instead it was extremely weak. Stereotypes were predicted as having a strong influence on every endogenous variable in the model with the exception of perceived value; instead the effect was only weak or moderate. The influence of a school computer course on the females' self-assessment of competency at home computer tasks was severely underestimated, as was the importance of liking on frequency of nonrecreational home use. Self-confidence, however, emerged a strong predictor of both liking and frequency of use; these relationships were predicted by the reduced female model.

As can be seen in Figure 7, female and male path coefficients on the female model to predict nonrecreational home usage are generally similar, although females' paths from stereotypes to liking and nonrecreational usage are relatively stronger than males' and males' path from computer competency to nonrecreational usage is stronger than females'. For both females and males self-confidence (.477 and .509) and computer competency (.457 and

.?22) are the strongest predictors of nonrecreational usage of home computers.

Summary of prediction of nonrecreational use of home computers. It appears the female model for nonrecreational usage of home computers provides a parsimonious and good fit for both the male and female data. This model shows self-confidence and degree of computer competency to be the major predictors of nonrecreational home use. Self-confidence in turn is most strongly influenced by computer competency, but less so for females (.463) than for males (.602). Computer competency with regard to home computer tasks is itself most strongly influenced by participation in a school computer course (.472 for females and .319 for males). The exogenous variables of parents' educational level, academic achievement, and stereotypes have relatively little effect on any of the variables, although stereotypes have a moderate association with self-confidence (.186, females; .201, males), liking (.200, females; .171, males), and frequency of nonrecreational access (.184, females; .140, males).

Predicting School Use of Computers

Full model for predicting school use of computers It is reasonable to expect many of the same types of influences in school use of computers as occurred in the predictions of recreational and nonrecreational usage of computers. For example, parents' educational level and having access to a home computer may be associated with a greater degree of computer familiarity and may also relate to the student's decision to study about computers in school as well as to the student's sense of self-confidence about computer use. Similarly stereotypes about computer users may serve either as facilitators or constraints on decisions to study about or otherwise use computers in school. Certainly the number of opportunities that arise for the student to use a computer as a tool in regular classroom settings such as science labs, mathematics classes, as a writing tool in language classes, or for information access and display in social studies classes is likely to contribute to the student's interest in computers as well as awareness of the value and application of computers in a number of different settings. Academic ability may also be related to school computer use if such use tends to be primarily the domain of students who take computer science courses or other courses with academic prerequisites.

Figure 8 shows the full model hypothesized to predict students' use of computers in schools. For clarity, paths associating every variable with every variable hypothesized to follow it in the model have not been drawn in; the full model predicts that the set of exogenous variables--parents' educational level, students' opportunity to use computers within regular classes, students' own familiarity with computers through personal home access, students' academic achievement level, and stereotypes the students endorse about computers--all influence each of the six endogenous variables. The six endogenous variables are hypothesized to influence one another in the order shown in the model, with prediction of school usage the terminal variable in the model.

Insert Figure 8 about here

Fit of the full model to male and female data relating to use of school computers. The model provides an extremely good fit for the prediction of school use of computers for both males and females, with the generalized regression coefficient for males equal to .979 and for females, .976. Using the model, 62.8% of the variability in school use can be explained for males and 58.2% of the variability explained for females. Table 3 displays the path coefficients for the prediction of school use of computers using the full model. Because of the exceptionally good fit of the model for both the male and female data, the full effects for each of the six endogenous variables are included.

Insert Table 3 about here

It can be seen from Table 3 that both similarities and differences can be found in the influence of different variables on the prediction of males' and females' use of school computers. Contrary to prediction, parent educational level has little influence and what it does have is largely negative--the less educated the parents the more likely the student will use school computers. As predicted, academic ability has a weak positive relationship with the criterion variables, but unlike the prediction, this relationship is weak. Unlike expectations, stereotypes about computers contributed very little to prediction of the criterion variables in the model. Having a home computer is more definitely a predictor of school usage and other associated variables for males than it is for females. Taking a computer course is the strongest overall predictor of school use for both males and females. The affective variables in the model--perceived competence, perceived value, self-confidence, and liking--contribute strongly to the prediction of all variables following them in the model, with perceived value of computer use strongly predictive of self-confidence about computer use for both males and females. This relationship is difficult to interpret and certainly was not predicted. Perceived value of computer use is more strongly related to liking for females than it is for males and an important predictor of overall frequency of school use for both genders. Self-confidence predicts liking more for females than it does for males but computer competency is a stronger predictor of variables following it in the model for males than it is for females. Liking has relatively little influence on school usage for either females or males.

Reduced model for prediction of males' school use of computers. While the full model presents a very good decomposition of the effects of different variables on the prediction of frequency of school use of computers, it is a highly complex model with 45 paths. A more parsimonious model with only 26 paths can be hypothesized for males. This reduced male model is shown in Figure 9 along with estimates of the relative strengths of the retained paths. The reduced male model reflects the assumption that males' school use of computers is most strongly influenced by their out-of-school experiences with computers as well as by their decision to participate in computer science courses at school. Labels indicating the hypothesized relative strengths of each of the paths for prediction of males' use of school computers are given on Figure 9 and repeated for convenience in Table 4 along with path coefficients for the model obtained for both male and female data.

Insert Figure 9 about here

Insert Table 4 about here

Fit of reduced male model for prediction of school use of computers. The reduced male model, with 19 fewer paths than the full model, provides a good fit for the male data, $R^2 = .939$. Compared to the full model which explained 97.9% of the variability in school computer usage for males, the reduced male model loses relatively little in predictive power but gains considerably in terms of explanatory value for the model. The male model also fits the female data well, with a generalized regression coefficient of .914. However, a comparison of the fit of the male data compared to its fit for the female data can be expressed by a Q value of .709, supporting the hypothesis that the assumed predictors most influential for males are not the same or are not weighted the same as those that predict females' use of school computers. Females appear to differ from males most on the influence of a home computer on school use and on the impact of computer course experience and of perceived competency on self-confidence. These relationships are stronger for males than they are for females. Hypothesized relative strengths were overestimated for males on the influence of parents' educational level on computer competency; the effect of a home computer on self-confidence and frequency of school use; the effect of academic ability on likelihood of taking a computer course, competency, and frequency of school use; and the impact of stereotypes on self-confidence and frequency of school use. There were also some estimates that were underestimated. These include the influence of subject use of computers on value and frequency of school use; of computer courses on perceived value and self-confidence; and the influence of competency on self-confidence.

Reduced model to predict females' use of school computers. While the male model to predict school usage of computers was based on the assumption that males are reasonably likely to make a straightforward transfer of their background and experience with computers into their likelihood of making use of school computers, it is reasonable to predict that females may mediate this transfer with a larger effect related to affective influences, such as stereotypes of computer users and personal self-confidence. There is evidence from research relating females' achievement and self-confidence in a variety of areas that suggests females are more likely than males to base their sense of self-confidence not on their own performance but on preconceived opinions about their competency (Wollcat, Pedro, Becker, & Fennema, 1980). Thus the reduced model to predict females' use of school computers predicts less influence of experiential variables than the reduced male model and more influence of stereotypes and self-confidence. The female model with predicted relative strengths of path coefficients is shown in Figure 10. The reduced female model has 21 fewer paths than the full model for prediction of school usage of computers.

Insert Figure 10 about here

<u>Fit of the reduced female model to predict school use of computers</u>. The reduced female model provides a good fit for the female data with respect to predicting school use of computers, with a generalized regression coefficient of .900. This compares favourably to the coefficient of .976 obtained for the females on the full model. However, it is not as good a fit for the females as was the male reduced model (with R^2 = .914 for female data on the male model). The female model also provides a good fit for the male data and in fact, the male data fit the female model (R^2 = .917) better than the female data fit the female model.

However, the male model provides a better fit for the male data (R^2 = .939) than does the female model. Table 5 displays the obtained path coefficients for both females and males on the reduced female model to predict school use of computers along with the hypothesized relative strength of the paths for female students.

Insert Table 5 about here

Examination of Table 5 shows that 11 of the 24 predictions about the relative contribution of the various paths retained in the female model did indeed match their respective relative weights. However, the model overestimated the importance of academic ability and stereotypes on females' frequency of school use of computers and underestimated the impact of subject use and computer competency as well as the effect of having a home computer on perceived competency. As predicted, however, self-confidence is the major predictor of both liking and frequency of use of computers in schools. Male data fit the model in these same ways with only one notable exception--taking a computer course was a moderate predictor of school computer use for males but a suppressor of use for females, as shown by a path coefficient of -.313.

Summary of prediction of school use of computers. The so-called male model for prediction of school use of computers provides a very good fit for both the male and female data and facilitates interpretation of the frequency of this usage through its omission of 20 paths from the full recursive while losing only 4% in predictive power for males and 6.2% for females. This model emphasizes the impact of prior experiences with computers in the school and the perceived value of computer use as the variables most associated with the likelihood of school use of computers. Contrary to predictions, the model does not support more than weak predictive power for parents' educational level, students' academic level, and stereotypes associated with computer users. Finally, as predicted, having a home computer contributes substantially more to the likelihood of using a school computer for males than it does for females, although the relationships are at best moderate (.195 and .064).

Comparison of Models for Recreational, Home Use (Nonrecreational), and School Use of Computers

Table 6 summarizes the fits of the various hypothesized models for computer use.

Insert Table 6 about here

It can be seen from a survey of Table 6 that the hypothesized models for recreational usage of computers were much less effective in explaining the obtained data than were either the nonrecreational home use or school use models. The models are strongly supported in these latter two categories. The differential explanatory power of the three models supports a major premise of this study--that different networks of influences impinge upon students' decisions to use computers for recreational purposes, for nonrecreational purposes at home, and in school. Also, it can be seen that the predicted influences thought to be more important for females than for males actually fit the male data better than the female data for each of the three types of computer usage. This suggests that affective variables also are important influences of males' computer-use decisions.

Students' decisions to take computer courses at school are not explained by the exogenous variables in the models and perceived value of computer use is poorly explained by the variables preceding it in the various model In contrast, self-confidence in school usage is particularly well explained by the full school model and liking of computer use is reasonably well explained in all of the nonrecreational and school use models.

Table 7 summarizes the influences of the predictor variables involved in the models.

Insert Table 7 about here

The unexpected finding in Table 7 is the overall lack of influence of parents' educational level and of stereotypes about computer users on frequency of usage in any of the three types of use. Having a home computer is a moderate predictor of likelihood of recreational use but means little in terms of frequency of school use. Self-confidence influences both home and school use and the likelihood of liking the use. Having taken a computer course is the strongest predictor of frequency of school use for both males and females when the full models are employed for prediction.

Summary

Overall, the models relate well to the data and support potentially important distinctions between predictors of computer usage with respect to recreational use, nonrecreational home use, and school use. These results indicate that it is inappropriate to make general statements about what influences students to use or reject computers; instead the context of usage must be considered. Also the results confirm the multivariate nature of influences impinging upon the decision to use or not use computers. Finally, gender differences in the nature and intensity of these influences are supported by the data, but not to the predicted extent. The relative similarity in the patterns of influences on males' and females' frequencies of the different types of computer use suggests that the consistent gender differences in frequency of use that have been documented by this study are primarily explained by variations in the value of particular variables rather than by the influence of different sets of variables.

The overall goal of the study--to validate the manifold model as a conceptual organizer for the critical examination of the complicated multivariate system surrounding adolescents' decisions to make use of available computers--has been supported by the study. The manifold model, with its five nodes, has been shown to be a flexible and powerful device for the empirical investigation of various theoretical reformulations of the model based on different contexts of gender and usage type. Particular decisions about reduced versions of the model in terms of specific gender/use type contexts have been tested and suggest many directions for future research and reformulation. The degree of success that we have had with regard to the general goal of the study--to develop a model capable of conceptualizing and supporting empirical investigators of the multidimensional system surrounding adolescents and computers--will depend on the utility of the manifold model for other researchers. We believe the utility is substantial.

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Table 1

Structure and Reliability of Study Questionnaire

Component	Number of Items	Alpha Reliability[a]
Demographic information	10	-
Objective questions relating to extent and frequency of computer uses for recreational, nonrecreational home, and school use	60	-
Held stereotypes about computer users	12	0.75
Social values		
Positive impact on society	14	0.76
Negative impact on society	10	0.73
Social concerns		
Felt personally	12	0.85
Expressed to friends	12	0.80

Note. [a]Based on 737 Grade 11 respondents in four provinces in Pilot 3 of the instrument validation process.

Table 2

Comparison of Predictors of Nonrecreational Use of Home Computers Using Full Model

Variable	Male[a]	Female[a]
Parents' Educational Level	.037[b]	-.135
Academic Performance	.142	.179
Stereotypes About Computer Users	.136	.193
Computer Course Experience	.200	.100
Computer Competency	.520	.483
Perceived Value of Computer Application	.138	.100
Self-Confidence	.484	.338
Liking	.374	.358

Note. [a]Students having access to a home computer; for males, N = 583; for females, N = 417. [b]Beta weights representing direct and indirect effects. Beta weights can be interpreted as describing what portion of one standard deviation of the criterion variable will change with a change of one standard deviation in the predictor variable.

Table 3

Full Model Path Coefficients for Variables Involved in the Prediction of School Use of Computers

Criterion Variables	Predictor Variables										
	Residual	Parent	Subject Use	Home Computer	Academic Ability	Stereo-types	Comp. Course	Comp. Competency	Value	Self-Conf.	Liking
					Males						
Computer Course	.970[a]	.039[b]	.015	.117	.080	.039					
Competency	.490	.036	.145	.628	.080	.061	.283				
Value of School Use	.738	-.021	.216	.135	.130	.051	.339	.316			
Self-Confidence	.264	-.010	.207	.168	.172	.052	.398	.377	.714		
Liking	.604	-.047	.126	.103	.227	.125	.330	.367	.360	.481	
Frequency of School Use	.372	-.022	.259	.154	.090	.066	.510	.358	.437	.395	.157

(Table continues)

Criterion Variables	Predictor Variables										
	Residual	Parent	Subject Use	Home Computer	Academic Ability	Stereo-types	Comp. Course	Comp. Competency	Value	Self-Conf.	Liking
					Females						
Computer Course	.987	-.064	.101	.006	-.007	.015					
Competency	.561	-.014	.095	.596	.063	.093	.192				
Value of School Use	.783	-.040	.222	.021	.073	.064	.345	.259			
Self-Confidence	.248	-.037	.233	.048	.100	.066	.363	.292	1.243		
Liking	.541	-.171	.182	.010	.173	.151	.300	.301	.475	.568	
Frequency of School Use	.418	-.137	.202	.012	.025	.034	.558	.270	.421	.368	.179

<u>Note</u>. [a]Percentage not explained by the model.

[b]Standardized beta weights for prediction of criterion variables.

Table 4

Path Coefficients for Male and Female Data on Hypothesized Reduced Male Model to Predict Use of School Computers

Criterion Variables	Predictor Variables										
	Residual	Parent	Subject Use	Home Computer	Academic Ability	Stereo- types	Comp. Course	Comp. Competency	Value	Self- Conf.	Liking
					Males						
Computer Course	.972[a]	.038[b]		.122	.084						
Competency	.493	.034	.141	.813	.093		.178				
Value of School Use	.753	(.020)[c]	.205	(.201)	(.049)		.339	.260			
Self-Confidence	.673	.007	(.061)	.193	(.068)	.082	.610	.658			
Liking	.617	(.011)	(.046)	(.174)	(.053)	.042	.339	.323		.516	
Frequency of School Use	.409	(.022)	.229	.195	.041	.005	.509	(.178)	.380	(.127)	.246

(Table continues)

Criterion Variables	Predictor Variables										
	Residual	Parent	Subject Use	Home Computer	Academic Ability	Stereo-types	Comp. Course	Comp. Competency	Value	Self-Conf.	Liking
					Females						
Computer Course	.997	-.057		.009	.002						
Competency	.569	-.008	.114	.600	.069		.207				
Value of School Use	.798	(-.019)	.182	(.114)	(.014)		.347	.186			
Self-Confidence	.773	.001	(.041)	.053	(.025)	.030	.379	.356			
Liking	.558	(-.009)	(.032)	(.073)	(.020)	.018	.314	.283		.609	
Frequency of School Use	.440	(-.030)	.114	.064	.026	.036	.563	(.132)	.320	(.157)	.257

Note. [a]Percentage of variance not accounted for by the model.

[b]Standardized beta weights.

[c]Values in brackets are indirect effects not predicted by male model.

Letters relate to hypothesized relative strengths of the paths for males.

Table 5

Path Coefficients for Male and Female Data on Hypothesized Reduced Female Model to Predict Use of School Computers

Criterion Variables	Predictor Variables										
	Residual	Parent	Subject Use	Home Computer	Academic Ability	Stereo-types	Comp. Course	Comp. Competency	Value	Self-Conf.	Liking
						Females					
Computer Course	.999[a]				-.008	.010					
Competency	.574	007[b]		.598	.071	.089	.217				
Value of School Use	.794	-.029	.163	(.110)	.077	(.019)	.312	.184			
Self-Confidence	.937		.241			.071					
Liking	.556		.180			.151				.644	
Frequency of School Use	.423	(-.004)	.159	(.014)	-.013	.020	-.313	(.023)	.126	.403	.192

(Table continues)