16. COMPUTER SOFTWARE IN STATISTICS EDUCATION: STUDENT VIEWS ON THE IMPACT OF A COMPUTER PACKAGE ON AFFECTION AND COGNITION

Gilberte Schuyten and Hannelore Dekeyser
University of Gent

The Data Analysis subdepartment of the department of Psychology and Educational Sciences is conducting several studies focus on the use of computers in statistics learning. One project investigates the computer as a learning environment for statistics. In an experimental setting, three different learning conditions are studied: computer-based independent learning, pen-and-paper-based independent learning, and lecture-based learning. The results of this research were presented at ICOTS IV Marrakech (Schuyten, Dekeyser, & Goeminne, 1994).

A second project focuses on student characteristics; that is, individual differences in dealing with verbal explanations, graphical displays, and formula. Their impact on the learning of statistics is investigated. In this study, the computer is used not only as a research tool to register the activities of the students in logfiles, but also as a didactic tool to explore the possibilities of computer-based materials for differentiation and individualization. Some findings were presented at ISI in Beijing in August 1995 (Schuyten, Goeminne, & Dekeyser, 1995).

A third project, discussed here, focuses on the added value of standard scientific computer packages. The added value of these packages to the traditional course (consisting of lectures and pen-and-paper exercises) is discussed. Students' views on the impact of the computer package on affection and cognition are collected with a structured questionnaire.

INTRODUCTION

The role of computer technology in education was and still is a much debated topic. Computers provide us with the opportunity to create entirely new learning environments for our students. Computers can be used in statistics education in many ways. They can be used as an illustration component in lectures, as a computation tool, as an electronic interactive textbook, as a research tool, and as a medium for thinking.

Many presentations at the ICOTS and IASE meetings have emphasized the benefits of computers in statistics education. In the early 1980s, Taylor (1980) added a third category "Tutee" to the well-known categories of "Tool" and "Tutor.” Tutee refered to the capacity of the computer to emphasize metacognition and to stimulate reflection on the learning processes. Now not only the use of computers to conduct exploratory data analysis (EDA) is emphasized, but also the ability of computers to provide multiple representations for stochastic information, particularly the graphical abilities of computers. Thus, computers provide both an exploratory aspect and a representational aspect (Shaughnessy, 1992). The requirements for an ideal software tool for supporting learning and doing statistics are given by Biehler (1993).

What about computer software in applied statistics courses for humanities and social sciences students? Not only do we want our students to learn statistics, but also we want them, as potential future users, to learn how to use a professional statistical package. In Flemish universities and at the Department of Psychology and Educational sciences, SPSS is generally accepted as a special purpose tool for doing statistics. The reasons for this are twofold: (1) students will use SPSS later in their careers; this will be true for those conducting research as well as for those in other professions where more and more data analysis is needed; and (2) technology is used as an amplifier; that is, it provides students more practice in less time, because it takes the burden of computing away from them.

STATISTICAL SYSTEM FOR DATA ANALYSIS AS A COGNITIVE TECHNOLOGY FOR STATISTICS EDUCATION

The use of a statistical system for data analysis not only affects student skills in handling the program but also their competence in statistics. It acts as a concrete tool and as "a representation and an object to think with" (Biehler, 1993, p.179). Following Pea (1987), "a cognitive technology is any medium that helps transcend the limitations of the mind (e.g., attention to goals, short-term memory span) in thinking, learning, and problem-solving activities" (p. 91). The ability to make external the intermediate products of thinking offers the possibility to analyze, to reflect on, and to discuss the thinking process.

In order to assess existing software and to guide assignments for computer workshops, the taxonomy of functions of educational technologies in mathematics education, as proposed by Pea, are also useful in statistics education. He distinguishes purpose functions, which may affect whether students choose to think mathematically, from process functions, which may support the component mental activities of mathematical thinking. Pea (1987) sees three *purpose functions* that could help strengthen intrinsic motivation: (1) the student has ownership of the problem, (2) learning events should be viewed as opportunities for acquiring new understanding and thus promote self-worth, and (3) knowledge for action, which means that knowledge should empower students to understand or do something better than they could prior to its acquisition. The five *process functions* dealing with the cognitive support provided to thinking include: (1) tools for developing conceptual fluency, (2) tools for mathematical exploration, (3) tools for integrating different mathematical representations, (4) tools for learning how to learn, and (5) tools for learning problem-solving methods. In assessing software for students enrolled in applied statistics courses, the purpose functions are of special interest, because those students are heterogeneous in terms of their mathematical background, most are not oriented towards the positivist paradigm emphasizing empirical quantifiable observations (Schuyten, 1991), and most lack confidence in mathematical thinking. Small project work on data concerning themselves could affect the students' ownership; that is, the success in running a program could affect their self-worth and empower them.

As for the process functions, the first, third, and fourth are particularly interesting in assessing professional software. In considering the first process function (conceptual fluency), the software program frees the students from conducting tedious calculations and from the possibility of making calculation errors, and frees up the mental resources of the students so that they can explore procedures and guide their learning. In terms of the third process function, the value of linking multiple representations for understanding was reported in the second study. However, a supplementary problem concerns the question:

"Is a statistical concept as represented in the software equivalent with that in an ordinary textbook?" This will be discussed below using the concept of a data matrix. For the fourth process function, the program traces students' problem solving and promotes reflective learning, the program monitors and assesses, the program helps students to control their activities, and the program helps the students learn how to learn.

COGNITIONS ASSOCIATED WITH DATA MATRIX

In his notation-representation foundations, Kaput posits a world of mental operations, which is always hypothetical, and a world of physical operations, which is frequently observable; these two worlds interact (Kaput, 1992). These physical operations deal with notation systems that are sets of rules, which are considered abstract until we decide to instantiate it using the material world (i.e., the physical medium) (Kaput, 1992). What are the cognitions associated with a data matrix as represented in traditional textbooks and as represented in professional software? How are these cognitions integrated? The classical notation of the object "data matrix" consisting of rows and columns in applied statistics courses is mainly used to display information. It is presented as a tool to organize data and as such it is connected with the object "tabulation." Later, by studying association, the object "contingency table" is introduced. Next, by studying differences between means of groups, the ideas of "dependent and dependent groups" become relevant. The cognitions associated with data matrix, tabulation, cross-tabulation, and dependent and independent groups need to be integrated. The notation systems used to express these concepts interfere, and students become confused and often ask, "Aren't they just rows and columns? What is the difference?"

Let us illustrate this using a simple data matrix. The data matrix in Table 1 consists of 6 units of analysis (cases) and 4 variables: sex, a question with a simple yes or no answer, pretest results, and posttest results. Except for the first column, which contains the identification codes, the body of the table consists of measurements. For the concept of assocation, crosstables are presented. In crosstables, the categories are the row and column headings, and the body of the table contains the frequencies of each combination of categories for the two studied variables. The crosstabulation shown in Table 2 still consists of rows and columns, but their meaning is different from those in Table 1 (the data matrix), and the body of the tables are different.

Hypothesis testing using two means (*t*-test) deals with two different situations: (1) the groups of measurements are independent (Table 3; i.e., "Is there a difference between the mean of the three men and the mean of the three women on pretest scores?") and (2) the groups of measurements are dependent (Table 4; i.e., "Do the means of pretest and posttest scores of the six cases differ?"). For the independent situation, pen-and-paper exercises are mostly presented as two columns of data and the rows are not relevant; in the dependent situation, rows are relevant and the two columns are taken out of the data matrix. The foregoing illustrates why many students have problems reorganizing the data represented in a data matrix into representations such as crosstabs or groups of measurements or vice versa. Many students lack flexibility in changing the view and cannot cope with different representations of the same data. However, what is the added value of the electronic data matrix? Why should the notation of a data matrix be more powerful in an electronic medium than in a pen-and-paper medium? Is the electronic data matrix more flexible in changing the view?

Table 1: The data matrix

ID	Sex	Pretest	Posttest	Question
1	1	6	6	1
2	2	4	7	0
3	1	8	7	1
4	1	5	9	0
5	2	6	7	1
6	2	7	6	1

Table 2: Contingency table of question with sex

	Sex	
Question	1	2
0	1	1
1	2	2

Table 3: Difference of means on pretest scores between men and women

Sex = 1	Sex = 2
6	4
8	6
5	7

Table 4: Difference of means between pretest and posttest scores

Pretest	Posttest
6	6
4	7
8	7
5	9
6	7
7	6

EMPIRICAL RESEARCH

Research design

Little is known about the educational impact of cognitive technology. Empirical testing of the exploratory new instructional curricula that embody the various functions Pea described is necessary (Pea, 1987). Case studies, effect studies of software, and evaluation of new curricular materials in natural settings of teaching are needed.

The applied statistics courses at the Faculty of Psychology and Educational Sciences consist of four components: lectures, pen-and-paper exercices, an independent learning introduction module to SPSS, and SPSS exercices. In this natural setting of a university course, it is not possible to isolate the effect of the software program. In order to explore the added value of computer software, a survey was conducted concerning student perception of the impact of the software on learning and doing statistics.

The statistics curricula

The applied statistics course is a two-year course. The first-year course deals with descriptive statistics, association, probability distributions, hypothesis testing, and estimation. The second-year course deals with effect size, testing and estimating measures of association, nonparametric tests, and parametric tests (*t*-test and one-way analysis of variance). In the first year, students get started with SPSS. The practical exam takes place at the beginning of the second year. This practical exam focuses on minimal competence needed to use SPSS (e.g., constructing a SPSS command using the SPSS menu, knowing how to use the glossary, saving a textfile in the editor Review, and so forth).

In the independent learning guide for SPSS, every step of the process of analyzing data with SPSS is based on a questionnaire that is filled out by the students at the start of the academic year. It contains questions on motivation for enrollment and attitude towards statistics, research, and computers. Every analysis is performed on these data and is discussed in terms of research question, hypotheses (if relevant), and content-linked interpretation. The first year independent learning guide contains an introduction to the computer program SPSS/STUDENTWARE and SPSS/PC+ (release 5.0), the SPSS editor REVIEW, the SPSS Menu, the output file SPSS.LIS, data preparation (units of analysis, variables, values, construction, and entry of the data matrix), an introduction to elementary descriptive statistics (frequency tables and statistics, barchart, and histogram), elementary data transformation (selection, recoding), bivariate analyses (crosstabs, regression analysis, Pearson's correlation), and plotting. The second year package deals with saving the data matrix and data definition into a SPSS system file, and using nonparametric tests and analysis of variance.

The students

In October 1994, 550 students were enrolled in the first course: In October 1995, 388 of those 550 students were enrolled in the second course. The practical exam, administered in October 1995, was taken by 375 of those 388 students. The questionnaire was filled out by 193 of those 388 students attending a lecture in April 1996.

The questionnaire

Students were questioned about their perception concerning the impact of SPSS on their attitude toward statistics and quantitative research, on self confidence, on their meta-cognitive skills, on how SPSS enhanced their understanding of statistical concepts, and on what they perceived as the added value of SPSS as a tool for "doing statistics." The impact of SPSS on attitude was measured by judgments made on a 5-point scale, where 1 = *Don't agree at all* and 5 = *Do agree totally*. Students rated their perception of the positive impact of working with SPSS on their attitude towards statistics, on their self-confidence in doing statistics, on their interest in quantitative scientific research, and on the metacognitive skills needed to analyze the research question, to select a procedure, and to guide and control their thinking process. The impact of SPSS on enhancing understanding of statistical concepts was measured for 30 statistical concepts using three response categories--promotes understanding, doesn't affect understanding, and hinders understanding.

From the list of 30 statistical concepts, 10 concepts were considered by the authors as irrelevant for assessing the impact of SPSS on enhancing understanding of statistical concepts taking into account the instructional curricula. However, these 10 concepts were included to provide information concerning the validity of the instrument. A concept was considered irrelevant if the SPSS activities did not focus on the concept (e.g., standard deviation, critical region, and so forth) or if the SPSS activities were not related at all to the concept (e.g., effect size, expectation, and so forth). The list was divided into two sublists--Form A and Form B. Each student gave his/her opinion about 15 concepts, 5 of which were supposed to be irrelevant. The variable "tool for learning statistics" was created from the 15 concepts. This variable indicates how frequent the “promotes understanding” category was crossed in the list of 15 concepts (scale 0-15). Students were also asked to give their global opinion about the impact of SPSS on enhancing their understanding of statistical concepts. The perceived added value for "doing statistics" was measured by 14 items to which the students could answer *yes, no*, or *don't know*. Based on these items, the variable "tool for doing statistics" was created. Students were also asked about their most positive and negative experiences in working with SPSS and their fluency in handling the software.

Background information

The results of the practical exam (which is graded on a scale of 0-5) administered in October 1995 are available as well as data concerning the motivation and attitude toward statistics collected from the students in October 1994. Because the practical exam focuses on the minimal competence needed to work with SPSS, a score of less than 3 means that the minimum competency requirements have not been met. Only 11% of the students tested did not manage to reach that level. Based on this score, two groups of students were formed: the high competency group with scores of more than 4 (n = 99) and the low competency group with scores of less than 4 (n = 40). Students with a score of 4 (n = 54) were excluded from the analysis in which high and low comptency groups were compared.

Results

The impact of SPSS on attitude toward statistics and on metacognitive skills

The results of the questionnaire administered in October 1994 indicate that the motivation of the students to enroll in courses at the Faculty of Psychology and Educational Sciences is based more on "helping people" [mean (M) = 3.9; standard deviation (SD) = .94; on a scale of 1-5] than on "doing scientific research" (M = 2.6; SD = 1.32; on a scale of 1-5). The impact of SPSS on attitude toward statistics (Table 5) was minimal (M = 2.9). The least positive impact was on stimulating interest in quantitative scientific research (M = 2.4); that is, 54% don't agree and only 17% felt SPSS was beneficial. There was also a small effect on metacognitive skills (see items Analyse a Question, Select a Procedure, and Control of Thinking Process in Table 5). The highest percentage of agreement was for "select a procedure" (33%), but this item also has a high non-agreement percentage of 39%. The most positive impact wa on attitude toward statistics with 32% non-agreement and 28% agreement.

Analysis of variance showed significant differences between the high and low competency groups for "statistics" (p = .012), "selfconfidence" (p = .026), and "control of thinking process" (p = .011). The means for the high competency group were higher.

Table 5: Questionnaire results

Note: Judgments were made on 5-point scores where 1 = Don't agree at all and 5 = Do totally agree; Categories 1 and 2 were collapsed into "Don't agree" and categories 4 and 5 were collapsed into "Agree"

Item	Impact				
	Don't Agree	**--**	**Agree**	**Mean**	**SD**
Statistics	32%	40%	28%	2.9	1.0
Self-Confidence	46%	35%	19%	2.6	1.0
Quantitative Research	54%	29%	17%	2.4	1.1
Analyse a Question	37%	35%	28%	2.8	1.0
Select a Procedure	39%	28%	33%	2.9	1.1
Control of Thinking Process	39%	35%	27%	2.8	1.0

Fluency in SPSS

Judgments were made on a 5-point scale concerning the students' perception of their fluency with SPSS. Only 23% of the students feel they can manage SPSS; 35% feel they cannot. Correlations with the affection/conation items were all significant, and the highest was with statistics ($r = .41$). The correlation between perception of fluency and the practical exam was not significant ($r = .14$)

Impact on understanding statistical concepts

Students were asked to indicate whether working with SPSS had an effect on the understanding of 15 statistical concepts. The categories presented were *promotes understanding*, *doesn't affect understanding*, and *hinders understanding*. In Table 6, concepts are ordered following descending positive impact on understanding, measured by frequency of the category *promotes understanding*. The last column indicates the authors' opinions concerning the relevance of the possible impact, taking into account the curricular materials.

The positive impact on the concept of data matrix is clear; this concept is followed by frequency table, histogram, variable, and frequency distribution. Also, an understanding of the research question is stimulated by SPSS (51% of the students). The concepts dependent and independent variable are clarified for 46% and 42% of the students. These findings about the impact of the software cannot be isolated from the impact of the curricular materials associated with the software. The impact on the concept of analysis of variance is very low, which can be explained by the fact that SPSS-work associated with this topic was done after the survey. These findings also indicate that more SPSS-work has to be integrated into the curricular materials concerning dependent and independent groups. The item concerning the global impact on understanding was answered in a positive way: 59% agree that SPSS enhanced understanding, only 2% felt that SPSS hindered understanding. The result for the variable "tool for learning statistics" is also rather positive (M = 5.43, SD = 2.82), taking into account that 5 of the 15 concepts could be considered irrelevant for the impact of SPSS. The impact of the software on understanding statistics is not affected by students minimum competence skills in handling the software. The means of the low competency and high competency groups were not significantly different.

Table 6: Positive impact of SPSS on understanding statistical concepts
(r = relevant concept, i = irrelevant concept)

Table 6A	%	r/i	Table 6B	%	r/i
Data Matrix	94	r	Histogram	73	r
Frequency Table	73	r	Frequency Distribution	67	r
Variable	69	r	Research Question	51	r
Unit of Analysis	56	r	Dependent Variable	46	r
Independent Variable	42	r	Measurement	40	r
Mean	37	r	Variable Concept	38	r
Independent Groups	32	r	Dependent Groups	34	r
Correlation Coefficient	32	r	Linear Regression	34	r
Level of Measurement	30	r	Median	30	r
Standard Deviation	23	i	Probability Distribution	30	i
Critical Region	18	i	Significant Result	27	r
Standard Error	16	i	Variance	20	i
Decision Rule in Hypothesis Testing	14	i	Critical Value	18	i
Analysis of Variance	13	r	Expectation	17	i
Effect Size	3	i	Standard Score	15	i

Impact on doing statistics

Students were asked to indicate if in their opinion SPSS-work was positive or negative for "doing statistics." The 14 items in Table 7 are ordered following descending positive impact on doing statistics. The top two include "Creating a data matrix" and "Saves you from calculations." The typical software characteristics "Error messages concerning thinking process" and "Menu-help for procedures" are appreciated by 2/3 of the students. Other process functions supporting mental activities such as "Error messages concerning typing," "Translating the research question into SPSS-language," and "Error messages concerning file-management" have a rather high number of students (20%, 18%, and 17%, respectively) expressing a negative impact on doing statistics. The underlying reason for this may be that these functions are positive when working with SPSS, but are irrelevant when doing statistics without a computer. Depending on how a student interprets it, he/she may answer yes or no. This could also explain the different appreciation for "Analysing research question" (74% positive) and "Translating the research question into SPSS-language" (52% positive). The item "Saves you from calculations," which refers to the first process function proposed by Pea (1987; i.e., tools for developing conceptual fluency), was appreciated by 4/5 of the students. The item "Own data," which refers to the first purpose function proposed by Pea (i.e., ownership), was appreciated by 73% of the students. The summing up of positive reactions produces the variable "tool for doing statistics" (on a scale of 0-14). Student opinion concerning the impact of SPSS on doing statistics was positive (M = 9.2, SD = 2.4, mode = 10). There was no effect of minimum competence on "tool for doing statistics" (p = .091).

Relation between affective variables and cognitive variables

Table 8 shows that the impact of SPSS on understanding statistics is correlated with the three metacognitive items, attitude, and selfconfidence, but it is not related with stimulating quantitative research nor with impact of SPSS on doing statistics. The impact of SPSS on doing statistics is only related to attitude towards statistics (Item 1) and self-confidence (Item 2), not to metacognitive aspects (Items 4, 5, and 6). Although the students found several aspects of SPSS positive for doing statistics, this is not related to a change in attitude towards quantitative research (Item 3).

Table 7: Impact of SPSS on doing statistics

Items	% Positive	% Negative
Creating a data matrix	83	4
Saves you from calculations	81	5
Analysing research question	74	3
Own data	73	3
You notice when “it doesn’t work”	69	11
Stimulates to look for errors	69	8
Error messages concerning thinking process	68	6
Menu-help for procedures	68	4
Interpretation of an output	68	10
Error messages concerning typing	62	20
Linking up theory and practice	61	10
Translating the research question into SPSS-language	52	18
Working together in the computerlab	47	12
Error messages concerning file-management	44	17

Table 8: Intercorrelations Between affection, conation, and cognition (*n* = 191)

Variable	1	2	3	4	5	6	7	8
1. Statistics	--	.66**	.42**	.41**	.40**	.46**	.23**	.19**
2. Self confidence		--	.50**	.39**	.38**	.39**	.19**	.19**
3. Quantitative research			--	.28**	.21**	.37**	-.00	.13
4. Analyse question				--	.69**	.64**	.28**	.13
5. Select procedure					--	.65**	.31**	.17
6. Thinking process						--	.29**	.17
7. Impact understanding							--	.15
8. Impact doing								--

Note: 2-Tailed Significance * = .01 **= .001

Discussion

The information provided by the students concerning the impact of the statistical software package should be treated carefully, because (1) software cannot be isolated from curricular materials; (2) student characteristics could clarify why some benefit and others do not; and (3) the questionnaire used here needs to be refined and open-ended items that probe for how and why explanations should be added. Tentative conclusions are that the software has a positive effect on understanding and doing statistics. It seems to support the component mental activities of statistical thinking. The results concerning the idea that the software enhances intrinsic motivation were not encouraging. Working with their own data helps the students, but their selfconfidence was not enhanced and their attitude toward quantitative research was not influenced in a positive way. It is rather promising that approximately 30% of the students express a favorable change in attitude toward statistics and in metacognitive skills. Cognitions associated with the data matrix are stimulated by the software package. The data matrix ranks first for understanding statistics and for doing statistics. In order to answer the questions stated above in Sections 2 and 3 (i.e., "Is a statistical concept as represented in the software equivalent with that in an ordinary textbook?" and "Is the electronic data matrix more flexible in changing the view?") more research and other research strategies are needed.

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