Computers Educ. Vol. 21, No. 1/2, pp. 141–149, 1993
Printed in Great Britain

0360-1315/93 $6.00 + 0.00
Pergamon Press Ltd

INDICATORS OF COMPUTER INTEGRATION IN EDUCATION

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Abstract—The large-scale introduction of computers in general secondary schools during the 1980s has resulted mainly in a focus on teaching students how to use computers. The current wave of thinking however is to emphasize more the integration of computers into the general learning experience, that is the use of computers as educational tools. For monitoring the complex process of integrating computers in education and for studying changes over time, indicators are needed. This article examines the quality of some indicators for measuring the integration of computers in education. Data from the IEA world-wide survey on 'Computers in Education' were used to construct such indicators. The results show that a very general rating by principals of the ways computers are used in a school can serve as a reliable and valid indicator of the degree of computer integration in schools.

INTRODUCTION

Whereas in the early 1980s only a relatively small number of schools were equipped with one or two microcomputers, by the end of the decade a majority of schools in developed countries were using computers for educational purposes, learning about computers or using them as educational tools. In general, the use of computers in education started in upper secondary schools, but slowly the use of computers also penetrated to lower levels, as indicated in Table 1, which shows data from Stage 1 of the IEA Computers in Education study (Comped)[1]. Moreover, Fig. 1 shows for lower secondary schools that countries where the infusion of computers is not yet complete tend to have started only recently to introduce computers in education.

Although it is reasonable to expect, by analogy to the use of computers at work, that the educational use of computers may lead to the replacing of old educational tools or approaches for new ones, such as computer-assisted instruction instead of instruction by teachers only, the data from the IEA Comped study show that this does not seem to have occurred yet to a substantial degree.

In contrast, it seems that the most popular use of computers in secondary education in 1989 was simply as an add-on to the already existing curriculum in the form of teaching students how to use computers and about computers more generally. Most secondary schools in many countries created a new subject, informatics, where students learn about computers. However, the use of computers as tools in existing subjects was by the end of the 1980s still not very widespread in secondary schools: Pelgrum and Plomp[1] showed that in most countries only a minority (less than 20%, except for New Zealand and the USA) of teachers of mathematics, science and mother tongue in lower secondary schools were using computers in their lessons, and even within this group about 75% use computers only very infrequently. Other estimates are even more pessimistic: 3% of USA teachers were 'exemplary computer using teachers', in 1989, according to Becker[2].

LEARNING ABOUT VERSUS LEARNING WITH COMPUTERS

The limited integration of computers in existing curricula by the end of the 1980s may be seen as a reflection of the main mode of thinking about educational computer use that has prevailed in the past decade. Hebenstreit[3], cited by Makrakis[4], makes a distinction between two main approaches, namely the technical and the pragmatic. The first approach advocates the importance of learning about computers via subjects such as informatics and emphasizes the need for teaching programming, while the second emphasizes the importance of learning with computers via

Table 1. Percent of schools using computers for instructional purposes in 1989 (adapted from[1, p. 18]) Instructional purposes means teaching/learning about computers as well as the use of computers as educational tools.

	AUT	BFL	BFR	CBC	CHI	FRA	FRG	GRE	HUN	IND	ISR	ITA	JPN	LUX	NET	NWZ	POL	POR	SLO	SWI	USA
Elementary																					
%	—	—	54	99	—	92	—	—	—	—	62	43	25	—	53	78	—	29	—	—	100
n	—	—	247	154	—	388	—	—	—	—	260	491	363	—	229	484	—	255	—	—	425
Lower secondary																					
%	62	78	93	100	—	99	94	5	—	—	—	58	36	100	87	99	—	53	—	74	100
n	614	287	186	138	—	419	410	433	—	—	—	409	363	27	262	123	—	266	—	1002	415
Upper secondary																					
%	100	98	93	100	61	99	100	4	100	7	82	80	94	—	69	100	72	72	94	98	100
n	309	260	198	138	419	388	198	461	311	880	184	341	662	—	250	133	573	220	85	324	425

— = data not collected.
Country codes are given on p. 143.

applications, e.g. using databases in history and geography, simulation in sciences, spreadsheets in mathematics. In the 1980s much emphasis was placed on *learning about computers*. Now *learning with computers*, or *curriculum integration*[5], that is, the use of computers as educational tools, tends to be more heavily advocated. One of the important questions is whether this wave of thinking is also reflected in educational practice. To find out what is happening in educational practice, and to monitor developments over time, we need to measure constructs like learning with computers and learning about computers.

DATA SOURCE

The data used here were collected in the 'Computers in Education' study that was conducted under the auspices of the International Association for the Evaluation of Educational Achievement (IEA). This study entailed data collection in 1989 (Stage 1) and 1992 (Stage 2). In Stage 1 national representative samples of schools were drawn. Via questionnaires, data were collected at three levels (elementary, lower secondary and upper secondary education) from principals, computer coordinators and teachers of informatics, mathematics, science, and mother tongue. The data presented here are from lower secondary education (ages 12–14).

The countries participating in Stage 1 of this study (with abbreviations to be used in the rest of this article) were:

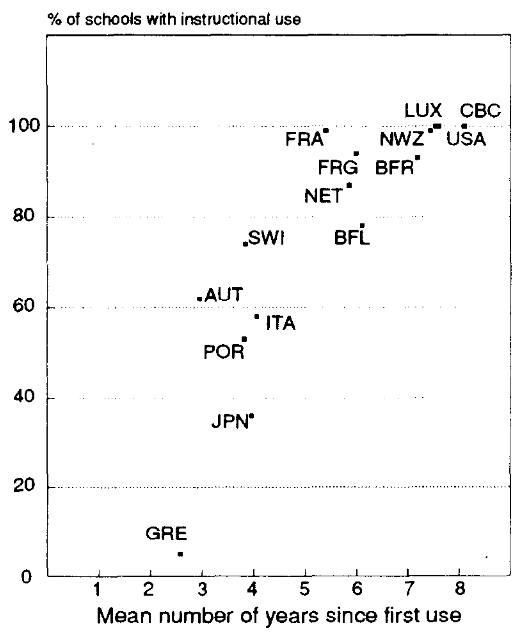

Fig. 1. Percent of lower secondary schools using computers for instructional purposes and mean number of years since first use per educational system. Source: database IEA-Comped Stage 1.

Table 2. Percent of principals in lower secondary computer using schools indicating types of use of computers in their schools, 1989

Ways of use	AUT	BFL	BFR	CBC	FRA	FRG	GRE	ITA	JPN	LUX	NET	NWZ	POR	SWI	USA
Students play games	53	12	27	62	54	24	29	19	19	33	27	53	43	24	82
Computer-assisted instruction	54	71	84	95	95	34	76	72	29	89	89	86	76	43	93
Demonstration	71	43	64	76	77	55	52	65	39	74	47	62	70	55	77
Word processing, etc.	69	61	71	99	69	76	62	65	30	82	77	96	75	76	78
Introduction about computers	84	89	84	96	75	81	98	88	37	85	93	93	81	84	87
Computer science	80	65	72	83	42	100	97	45	19	85	44	67	67	62	68
Catching-up	7	29	25	61	58	6	9	24	20	7	56	34	23	11	71
Enrichment	20	29	31	77	57	6	2	32	11	7	33	69	49	14	84
Tests on computer	8	21	29	62	36	3	40	43	8	37	37	55	36	10	40
n	364	318	169	137	366	372	56	237	240	27	235	122	144	631	311

Source: database IEA-Comped Stage 1. Country codes are given below.

AUT: Austria
BFL: Belgium-Flemish
BFR: Belgium-French
CBC: Canada-British Columbia
CHI: China
FRA: France
FRG: Federal Republic of Germany
GRE: Greece
HUN: Hungary
IND: India
ISR: Israel
ITA: Italy
JPN: Japan
LUX: Luxembourg
NET: Netherlands
NWZ: New Zealand
POL: Poland
POR: Portugal
SLO: Slovenia
SWI: Switzerland
USA: United States of America

Details of the design of the research (instrumentation and samples) as well as a full description of results from Stage 1 can be found in Pelgrum and Plomp[1].

MEASURING COMPUTER INTEGRATION

The Comped database contains variables that are of potential relevance as indicators of computer integration at the school and teacher level. At the school level, questions were asked of the principals and computer coordinators about the ways computers were used in the school in general as well as their use in school subjects. At the teacher level, questions were asked about the subject matter for which computers were used and which topics teachers addressed in teaching about computers.

To characterize the types of use of computers in school, principals were asked to indicate for which activities computers were used at their school. This list as well as the percent of affirmative responses per country is shown in Table 2.

A principal component analysis of the responses of the principals (Table 3) shows a distinction between ways of use that can be interpreted as learning with (Factor 1, abbreviated as LEARNWITH) and learning about computers (Factor 2, LEARNABOUT). Noteworthy is that the use of computers for the applications word processing, databases and spreadsheets is included in Factor 2. This may signify that these applications, in 1989, still tended to be used more as objects of study than as tools for learning.

The scores on Factor 1 can be used as an indicator of emphasis on integration of computers at the school level, whereas the scores on Factor 2 may serve as an indicator of emphasis on learning about computers. However, as the simple sum of scores on the first five items with a high loading on Factor 1 correlate 0.95 with the factor score, we will use this sum for reasons of simplicity of presentation and easiness of interpretation by the reader[172 cases (5%) with a score of zero on both LEARNWITH and LEARNABOUT were excluded from further analyses because these scores reflect inconsistencies in answering the questionnaire]. The reliability of the scale LEARNWITH across countries is reasonable (0.67), while within countries the reliabilities are 0.47 on average and vary between 0.36 and 0.60 (Greece being an outlier with 0.13, due to items with no variance). The reliabilities of the scale LEARNABOUT are 0.53 across countries, and varies between 0.15 and 0.78 within countries, with an average of 0.48. The correlation of LEARNWITH and LEARNABOUT across countries is 0.07.

Another possible global indicator for the degree of integration of computers is the number of traditional subjects, excluding computer studies, in which computers are used in a school. This indicator (SUBJECTS) is calculated by counting the number of subjects from a list of six (mathematics, science, mother tongue, foreign language, creative arts, and social studies) where computers were used. The reliability of this measure across countries is 0.63 and it varies between 0.27 and 0.75 within countries with an average of 0.48, which is roughly comparable with the reliabilities for LEARNWITH.

The correlation between LEARNWITH and SUBJECTS is 0.28 across countries and varies between −0.20 and 0.41 within countries with an average of 0.18 which indicates that these measures should be considered as indicators of different constructs.

To determine which of these measures would be the most powerful indicator of computer integration, we analyzed for both indicators how they covaried with other variables.

CHOOSING BETWEEN ALTERNATIVE INDICATORS

A first consideration for choosing between these indicators was the results of the principal component analyses presented above in Table 3, which showed that the LEARNWITH items can be distinguished from the LEARNABOUT items. The measure SUBJECTS is conceptually less clear, as the use of computers by teachers in traditional subjects may still include teaching about computers. To answer the question whether each of these measures can discriminate between the ways of computer use by teachers, we analyzed to what extent teachers from traditional subjects use computers in an integrative way as well as teach about computers in their lessons. The number of subject-matter topics (TOPWITH) for which a teacher indicates computer use serves as a measure of integrative use at the teacher level, whereas the number of computer education topics covered, such as computers and society, applications, and principles of programming and hardware (TOPABOUT), reflects the emphasis placed on teaching about computers. The maximum possible scores for each subject were adjusted to a 10-point scale to compensate for variation in the total number of topics among the questionnaires for teachers from different subjects (mathematics, science and mother tongue). 30 cases (2%) with a score of zero on both TOPWITH and TOPABOUT were excluded from further analyses because these scores reflect inconsistencies in answering the questionnaire.

The correlation between TOPWITH and TOPABOUT is very low (−0.11) across countries. It varies between −0.07 and 0.40 within countries, with an average of 0.15, which suggests that the measures reflect different constructs.

The rationale for selecting TOPWITH and TOPABOUT as indicators on the teacher-level is that although they are rough estimators due to unequal content covered per subject, they covary in a meaningful way with different categories of other variables, which by themselves were hypothesized to reflect either learning with or learning about computers. These variables concern the approach followed by teachers in using computers, the applications used by students according to teachers, and the knowledge of information technology possessed by teachers. Table 4 shows the two-factor

Table 3. Factor loadings of ways-of-use ratings of principals in lower secondary schools from all countries (n = 3628), 1989

Ways of use	Loadings on Factor 1 (LEARNWITH)	Loadings on Factor 2 (LEARNABOUT)
Computer-assisted instruction	0.68	0.17
Catching-up	0.74	−0.11
Enrichment	0.79	−0.02
Tests on computer	0.58	0.12
Students play games	0.51	0.10
Demonstration	0.39	0.19
Word processing, databases, etc.	0.25	0.62
Introduction courses about computers	0.11	0.76
Computer science	−0.08	0.78

Source: database IEA-Comped Stage 1.

Table 4. Factor loadings for answers to different categories of questions from computer using teachers of mathematics, science, and mother tongue in lower secondary schools (n = 1432), 1989

	Loadings on	
	Factor 1	Factor 2
Teacher uses computer for:		
remediation of slow learners	0.68	−0.11
enrichment of fast learners	0.54	0.12
testing of students	0.43	−0.12
providing actual instruction	0.39	0.13
Students use:		
tutorial programs	0.56	0.04
drill &practice programs	0.51	−0.08
educational games	0.50	0.04
simulation programs	0.26	0.08
spreadsheet programs	0.01	0.55
database programs	0.03	0.53
BASIC	0.04	0.35
word processing programs	−0.07	0.33
Teacher can/knows:		
evaluate usefulness of software	0.52	−0.01
adapt instructional software	0.47	0.11
criteria for printer quality	0.01	0.64
what a relational database is	0.11	0.60
what a bit is defined as	0.08	0.51
TOPWITH	0.68	−0.10
TOPABOUT	−0.07	0.72

Source: database IEA-Comped Stage 1.

solution for the entire sample of teachers, but in further analyses the same structure held within the subsamples of teachers from the different subjects.

For countries with sufficient cases ($N > 40$), mean country scores are plotted for TOPWITH and TOPABOUT against LEARNWITH and SUBJECTS in Fig. 2.

Furthermore, the school-level measures LEARNWITH and SUBJECTS were disaggregated to each teacher in the sample of that school. In this way a school-measure can be seen as environmental factor or climate under which teachers work. The solid lines in Fig. 2 are the plots of disaggregated school-level LEARNWITH and SUBJECTS with the teacher-level TOPWITH and TOPABOUT measures.

It is evident from Fig. 2 that the indicator SUBJECTS covaries less clearly with the teacher measures than LEARNWITH: SUBJECTS discriminates less, both between countries and, more importantly, between teacher activities. Especially for teaching about computers (TOPABOUT) the curve is less steep compared to LEARNWITH. These plots confirm the idea that the indicator SUBJECTS conceptually suffers from the lack of recognition that the use of computers in traditional subjects may still include a substantial amount of teaching or learning about computers. Teachers of traditional subjects in schools which emphasize integrative use, according to LEARNWITH, indeed seem to use the computer relatively more for subject matter than computer-related topics. This does not mean that in those schools computer-related topics are not addressed because, as stated before, most schools have created a separate subject for that purpose.

The analyses presented so far show that the measure LEARNWITH is reliable across countries. The measure has face validity, whereas the covariation with variables measured at the teacher level can be seen as a further corroboration of its validity. Hence, this measure can be used as a global indicator for the degree of integrative use of computers in schools. In the next section the face validity of this indicator is further illustrated by showing how it covaries with other variables.

INTEGRATIVE USE OF COMPUTERS IN RELATION WITH OTHER VARIABLES

Although the main question addressed here is how to measure computer integration, the most provoking question is how can computer integration be improved. To answer this question, we need to know to what extent computer integration covaries with other variables that can be manipulated. Although it would be beyond the scope of this article to discuss this matter extensively, it may be of interest to the reader to inspect some of the results of analyses on the data from Stage 1 of the

IEA-Comped Project, that are discussed in more detail elsewhere[6]. In Fig. 3 a few interesting findings are shown.

The plot of integrative use and the number of years that have elapsed since computers were introduced in a school (Fig. 3A), suggests that integration of computers is a matter of time. However, other circumstances also seem to play a role. The degree of integration of computers seems to covary with the emphasis put on educational reasons for introducing computers (Fig. 3B), which means that schools which started to use computers to improve educational outcomes tend to use computers in a more integrative way than schools which put less initial emphasis on these

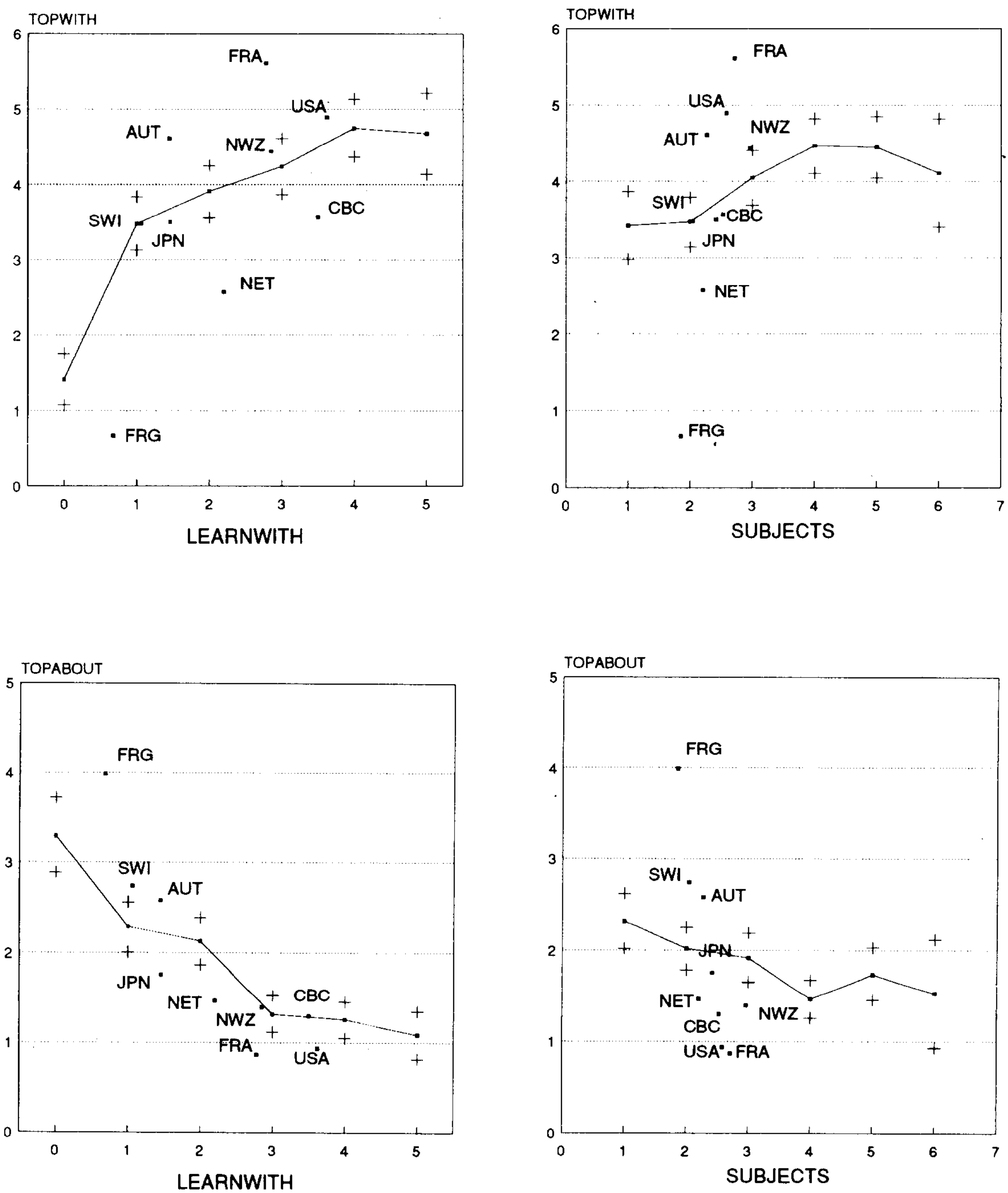

Fig. 2. Plots for lower secondary schools of country means and school means across countries (solid lines) for LEARNWITH and SUBJECTS vs TOPWITH and TOPABOUT (+ indicates 95% confidence limits). Source: database IEA-Comped Stage 1.

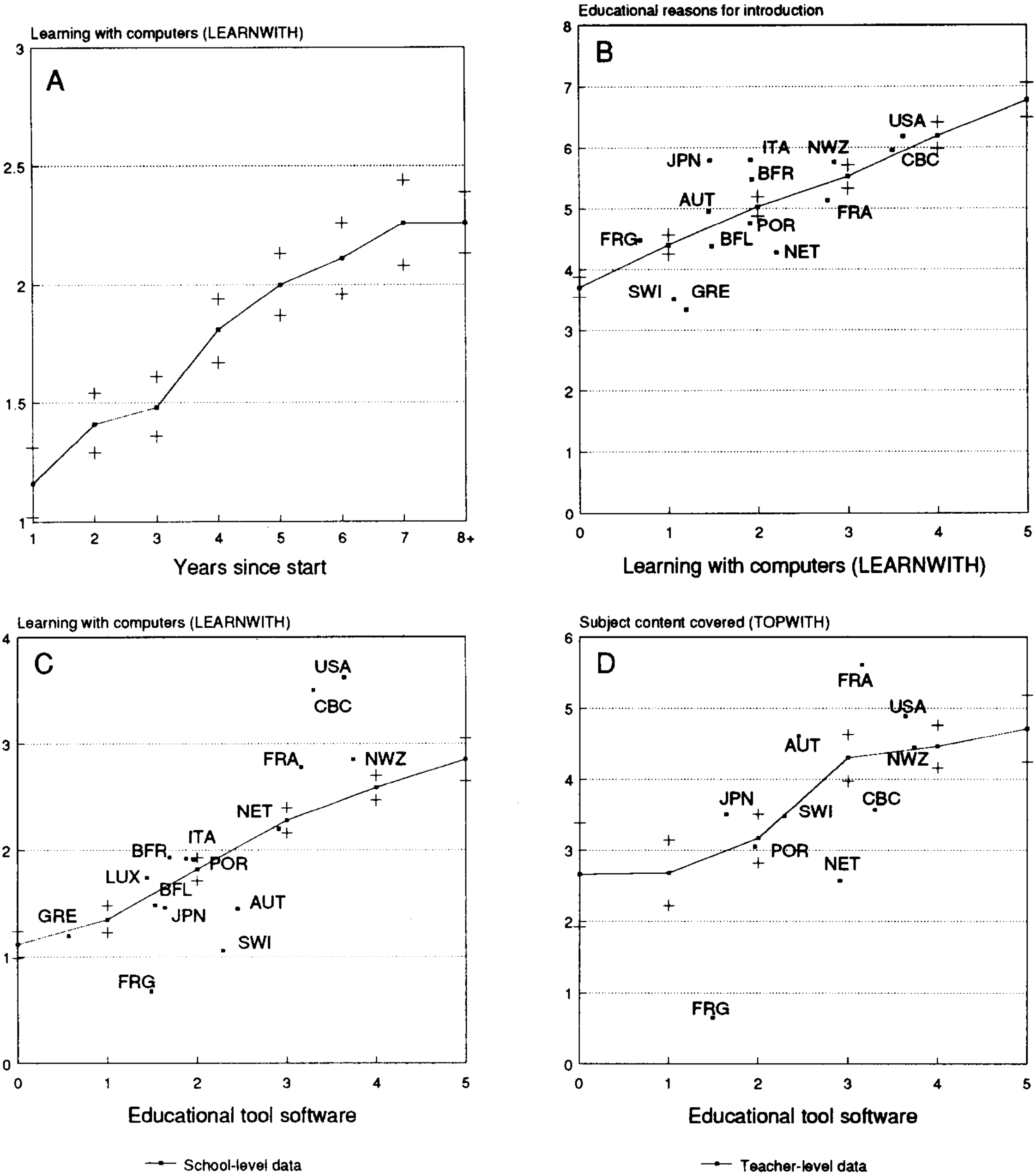

Fig. 3. Plots for lower secondary schools of country means and school/teacher means across countries (solid lines) for integrative use of computers vs educational reasons for introducing computers, years since start, and availability of educational tool software (+ indicates 95% confidence limits). Sources: Fig. 3B[7]; other figures: database IEA-Comped Stage 1.

reasons. Figure 3C shows that the integration of computers is clearly associated with the availability of educational tool software: the more educational tool software, the more integration. Although, there is still the classical problem of interpreting covariation in terms of causality, it seems reasonable to suppose that the availability of educational tool software could be a stimulating factor in promoting integrative use of computers. Such an interpretation is consistent with the finding that the availability of more educational tool software is associated with a larger number of subject-matter topics for which teachers use computers during their lessons (Fig. 3D). A regression analysis of integrative use on only three independent variables (availability of educational tool software, number of years of experience of schools in using computers, and the emphasis on educational reasons for introducing computers), shows that 32% of the variance in integrative use can be explained.

Finally, we can look at the scale LEARNWITH in more detail. Figure 4 shows for each sum score on this scale the proportion of respondents answering the item affirmatively. If we interpret these trace lines in the same way as for items of achievement tests, Fig. 4 shows that computer-assisted instruction is the core of integrative use, while computer-assisted formal testing apparently is the least-practiced type of use. Remediation/catching up, enrichment, and educational computer games have an intermediate position.

SUMMARY AND DISCUSSION

The question of how computer integration into non-computer subjects and settings can be measured has been answered by showing that an indicator can be constructed which is easy to measure, internally consistent, and valid to the extent that it covaries with other variables in a plausible way. This, of course, does not mean that other and even better indicators may be devised. For instance, one may argue that it would be better to take into account more in-depth information as to how students exactly use computers, e.g. frequency of use, which programs, and how used. However, such measures are much more expensive and need to be collected via students and/or trained observers. Stage 2 of the IEA-Comped study offers some possibilities to study these student-level measures, as during this stage (with data collection in 1992–1993) the school- and teacher-level measures from Stage 1 will be complemented with student-level measures.

Nevertheless, as shown, a global indicator which is useful for the monitoring of computer integration in education can be achieved cost-effectively. Hence this indicator can be considered as a potentially useful variable in future research in this area. As one can see above, the range of the current scale is quite limited, and for a few countries (like the USA, Canada-British Columbia and New Zealand) scores tend to reach the scale's ceiling. Therefore, it would be advisable in future applications to try to increase the scale range by adding additional items to the scale and/or by constructing a more differentiated set of response categories for each item in the scale.

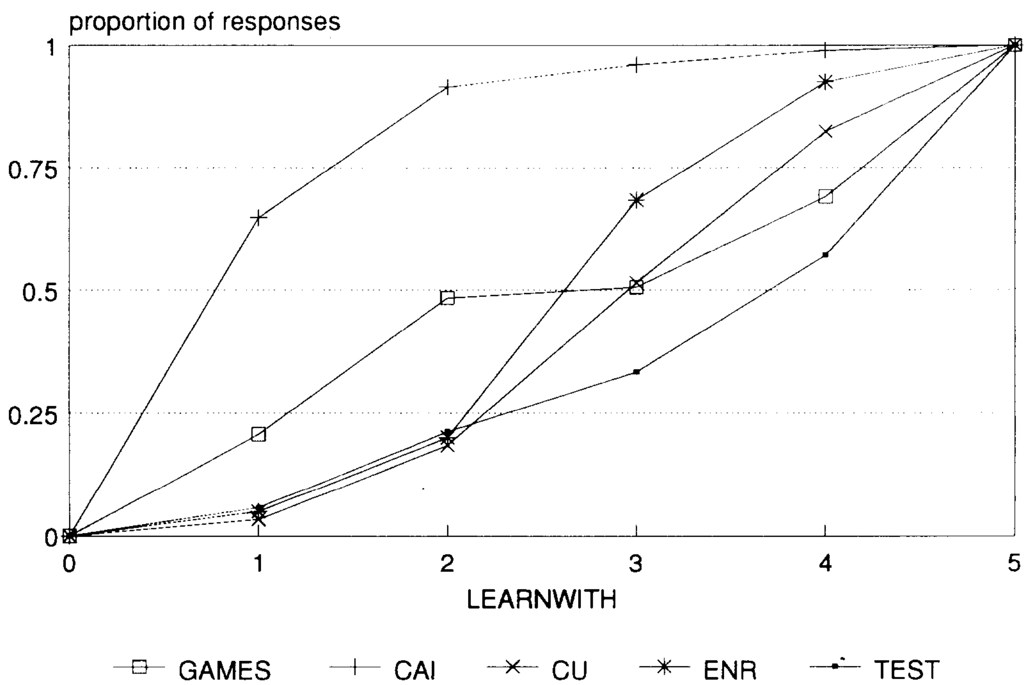

Fig. 4. Plots of proportion affirmative responses for each sum score per item of the LEARNWITH scale. GAMES = educational computer games; CAI = computer-assisted instruction; CU = remediation by computer; ENR = enrichment by computer; TEST = computer-assisted formal testing. Source: database IEA-Comped Stage 1.

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