Investigating Cross-national Educational Software Portability: the Case of Electronic Workbenches

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SUMMARY

A critical issue with respect to improving an international market for educational software is that of portability. What features are most likely to facilitate or thwart the portability of an educational software package? Under what conditions would the cross-national use of a software package be more likely to occur? These questions have formed the framework for a four-year study based at the University of Twente in The Netherlands involving researchers and practitioners from more than 20 countries. Part of the study has been focused on the examination of so-called 'electronic workbenches' as particularly promising candidates for cross-national educational software portability. This paper summarizes international experiences with a particular electronic workbench (*EWB* for electronics instruction) as a basis for more general recommendations about workbench simulations as a type of educational software well suited for cross-national portability.

CROSS-CULTURAL EDUCATIONAL SOFTWARE PORTABILITY

The term 'portability' is often thought of in a technical sense, 'the degree to which you can move an application from one computer to another unchanged and get the same results' (Dahlstrand, 1984, p. 18). It has been long applied in software engineering, as 'a measure of the ease with which a program can be transferred from one environment to another. If the effort required to move the program is much less than that required to implement it initially, then we say that it is highly portable' (Poole and Waite, 1977, p. 183). Improving the portability (sometimes called 'target-environment independence') of software, or at least of components of software, has been long established as a goal in software engineering, for reasons related to economy, maintenance, and performance efficiency (see, for example, Ratcliff, 1987).

Portability of educational software

However, portability applied to educational software has layers of complexity extending far beyond those of different delivery platforms. Not only must technical aspects be considered, but also a number of other complex clusters of factors. Collis and De Diana (1990c), after a review of the literature, identified the following three sets of factors as each being critical to the likelihood that educational software made for one setting will be used in a different setting:

Educational factors:

Relating to relevance of the software to local educational needs and priorities, to the curriculum, to harmony with locally prevalent instructional approaches and classroom organization patterns, and to the experience and role perceptions of teachers (see for example, Ballini and Poly, 1988; Ely, 1990)

Social/cultural factors:

Relating to tone, style and language of communication used in the software as well as references used, but also involving issues relating to cultural identity and political sensitivities with regard to using educational resources 'not made here' (Ely, 1989; Kearsley, 1990; Murray-Lasso, 1990; Sukaviriya and Moran, 1990)

Organizational factors:

Relating to local procedures for decision making about purchase, distribution, maintenance and ownership of educational support materials, and also to cost-related considerations (for example, Oliveira, 1990).

The general experience from the field is that these human-related aspects of educational software portability are of considerably more long-term impact than are the technical aspects, an observation that Bork, long active in this area, made as long ago as 1976, and which he has not had reason to modify in the 1990s (Bork, 1976, 1990).

Global importance of educational software portability

There are a number of reasons why cross-national educational software portability is an issue of global importance. These reasons relate not only to the issue of improving global inequities in access to educational resources, but even more fundamentally to the viability of the educational software market itself.

Economic motivations

A major motivation for an interest in educational software portability is directly related to economics – the importance of saving cost and time in the labour-intensive development process. A steady improvement in the cost factors associated with educational software development is necessary in order to better stimulate the commercial market for educational software, both from the perspective of the producer and of the consumer (Oliveira, 1990; OTA, 1988). Even in comparatively wealthy countries, schools are only willing to pay a certain maximal amount for software, even though the development costs of the software are considerably higher (Netherlands Ministry of Education, 1989, p. 23). Portability relative to the potential range of sales of software products is of importance in the stimulation of the still-struggling educational software market;

without this market gaining strength, a supply and demand mechanism will not be found that stimulates lower costs and broader choice in software and thus a critical mass of consumers (Collis and De Diana, 1990c; Oliveira, 1990).

Implications for small and poor countries

These economic arguments intensify in the context of small or less-developed countries. 'Small countries simply cannot fund the cost of their educational software development' (IFIP Working Conference, 1989). Less developed countries are not only limited in financial means, but also experience a shortage of qualified manpower, scarcity of up-to-date development tools and poor access to technological advances (see, for example, Oualid, 1989). The shortage of adequate numbers of trained personnel to support a local software development industry is also a strong motivation for software portability, from the side of the disadvantaged country. 'Reinventing the wheel' is not only costly and inefficient for many poor countries, but is not even an option (Feinstein, 1989; Murray-Lasso, 1988). They must get software from outside or not have it at all; a situation with both economic and moral implications for wealthy countries with a variety of software for their students (see Weston, 1989; and Wolansky and Iyewarun, 1989 – for perspectives relative to the belief that those who have should share with those who do not).

Improved insights

There are also other reasons to strive to improve educational software portability. Better insights can be obtained about the overall complex situation that surrounds educational software use in schools if experiences with the same package in different cultural and educational settings can be compared. Better guidelines for design and decision making, relative to software as candidates for increased portability, can only be obtained if a large range of experience is synthesized (Collis and De Diana, 1990c).

The Portability Project at the University of Twente

All of these considerations formed the basis for a four-year study, now drawing to a close, in the Faculty of Educational Science and Technology at the University of Twente in The Netherlands. The

project has as its overall goal the development and validation of a global model for improving the portability of computer-related educational resources (for a summary, see Collis and De Diana, 1990a). It is intended that this model will be of use to two major groups – designers of educational software, and local decision makers who must determine if a package from ‘outside’ will be acquired for an educational system or if instead locally made products should be chosen. The research has generated a number of sub-activities including an international forum (see Collis and De Diana, 1990b); experimentation in Mexico (Mols, 1991), in Bulgaria and Egypt (Lanzing, 1993b), and in China (Dong and Zhang, 1992; Zhang and De Diana, 1993; Zhu and Collis, 1992); in Canada (Koenig and Collis, 1992); in The Netherlands (Collis *et al.*, 1991); and cross-nationally (De Diana and Collis, 1990; Wetterling, *et al.*, 1992b). From these and other sources of experience, it has become clear that certain types of educational software are better candidates for portability than others. Nagtegaal, for example, says that ‘products that have characteristics of an educational tool or an exploration environment have more potential to be used in a variety of educational contexts than have drill and practice or instructional environments’ (Nagtegaal, 1990, p. 189) but that these types of software also require the most complex relational context of the various types of software, requiring new approaches to instruction and classroom management, a situation found to be difficult for teachers to handle, even with locally made software (see, for example, Pelgrum and Plomp, 1991, for an analysis of computer use in 19 countries). Thus, ironically, portability potential may increase with content-free software but actual usage may not follow.

Workbench-type simulation packages and the ‘Electronics Workbench Study’

We have general evidence that teachers have difficulty implementing content-free, tool-type software (see also, for example, Watson, 1993). However, based on our analysis, ‘workbench’-type software where the computer makes available a simulation of some aspects of a well-equipped laboratory in a certain subject area, appears to be a better candidate for portability than either content-free packages or content-specific

instructional packages. Thus as part of the overall University of Twente Portability Project, we decided to conduct a number of investigations using a particular workbench-type software package, for electronics instruction, in order to examine our hypothesis that workbench-type software is a relatively good candidate for cross-national portability, and also to contribute more insights to our general investigation of educational software portability. In the following sections we introduce and then summarize those investigations.

ELECTRONICS INSTRUCTION AND THE ‘ELECTRONICS WORKBENCH’

Computer simulations in electronics education

Electronics instruction is a complex activity. It is important to present domain knowledge, but at the same time students need practical experiences in the application of electronics concepts to circuit building. ‘Fundamental to this requirement is the need to provide facilities to enable students to exercise their skills in environments in which design and fabrication efforts, if unsuccessful, would not be catastrophic’ (Barker and Manji, 1988). Such practical training occurs through experiments relating to the application of electronics concepts in order to better understand the theory of electricity, and also through experimenting with a great diversity of electronic devices and circuits, by construction of electronic circuits (analog and digital), and by taking measurements while using electronic circuits.

However, because of growing student numbers and growing costs of providing supervised hands-on experiences with both analog and digital electronics environments, alternative ways of providing this experience are becoming increasingly important (Barker and Manji, 1988; Thasing, 1989). Also important is the fact that many science teachers in secondary schools are often uncomfortable about or unable to organize adequate laboratory experiences for their students, partly because of their own lack of experience, partly because of difficulty in setting up and managing science hands-on activities (see Doran, Tamir and Bathory, 1992, for a six-country analysis that shows that in some countries students have almost no hands-on laboratory experiences in science).

Simulation of hands-on experiences in electronics with workbench-type software

One way to deal with these problems is to simulate the functioning of diverse equipment in computer-based 'workbench simulation' programs that can be given to the student to use in the school computer laboratory or at individual computers (Smith and Pollard, 1986). There are several workbench-simulation packages available for this type of simulated practical experience in electronics education (Balle, Dubreuil and Bouret, 1992; Lawson, 1992; Mulema, 1992). There are differences between these programs in range and flexibility, price, instructional support, and user interface (see, for example, Bonekamp, 1991; and Rutten and Wong, 1991, for two such comparisons). The packages are similar, however, in that they offer, through the use of on-screen 'tools', the opportunity for rapid simulated construction of electronic circuits and give feedback on the performance of these circuits through the coupling of various simulated measuring instruments to the on-screen circuit.

The Canadian Package, 'The Electronics Workbench'

One of these packages is 'The Electronics Workbench (EWB)' (Interactive Image Technologies, 1989). The purpose of the Electronics Workbench is to learn the theory of analog or digital electronic circuits by practising with simulated models. The test instruments in the program have many of the basic controls found in the 'real' laboratory situation. It is possible in EWB to perform experiments building simulated electronic circuits (either analog or digital) on a simulated workbench, where feedback is given as to conduct of the circuit when simulated charges are sent through it. The level as well as the size and complexity of the circuits can vary and different measuring instruments can be applied to test the constructed circuits. Various display and transfer options are possible to save and further study the results of the circuit-building experiences. The user interface in EWB is mouse driven (but keyboard use is also possible), and uses windowing techniques. The package comes with on-line help options, organized in a hypertext-linked interrelated text file which is capable of being

adapted by the instructor. All of this results in a training experience similar to that which the student would get if the student were using real circuits on a real workbench (Bonekamp, 1991; Interactive Image Technologies, 1989). Figure 1 shows typical screen displays of the analog and digital workbench environments in EWB.

EWB was developed in the context of a multifaceted program to stimulate and support the use of computers in schools in Ontario, Canada (see Collis, 1992, for a fuller description). The task of EWB was to be a software package, ready for use in Ontario secondary and vocational educational settings, that would essentially simulate an electronics laboratory – with both digital and analog equipment – without requiring the substantial investment of fully equipped labs and qualified instructors for each secondary and vocational school setting in Ontario. As an additional challenge, EWB was expected to equalize opportunity for quality electronics experiences in a province where there are two official languages and where portions of the population live in remote and distant small communities in a widespread area. Finally, the package had to run on various computer platforms and be as accessible and useful to an instructor in a remote centre with little electronics background as it would be to a specialist instructor in a large urban school (and now, also, in higher vocational education settings and industrial training centres). Thus the package must be 'portable' in the full sense of the term (Collis and De Diana, 1990b) and also be perceived to be effective relative to its cost of use; otherwise, teachers would not use it, the Province would not support it, and the costs of the developer would not be recovered.

That the package is perceived as meeting these expectations can be supported by the fact that in approximately five years it has become widely used not only in Ontario settings, but throughout Canada and in more than 20 other countries in a variety of educational levels and settings. Such widespread use of an educational software package is unusual (Collis *et al.*, 1992). Thus EWB was chosen as an appropriate candidate for a series of analyses relative to the hypothesis that workbench-type software is a relatively strong candidate for educational software portability.

Figure 1. Basic workbench environments, analog and digital variations, EWB software package (1989 version). (Reproduced with permission of Interactive Image Technologies, 700 King Street West, Suite 815, Toronto, Ontario, Canada, M5V 2P6.

Analyses relating to the portability of EWB as an example of a workbench package

We undertook a number of different types of analysis relative to the portability of EWB. We worked with it ourselves, to evaluate its features relative to its design and user-friendliness (Dong and Collis, 1993; Siteur and Hettinga, 1992). We examined its flexibility relative to different approaches to curriculum (as transmission, as transaction, and as transformation – Miller and Seller, 1985; Holstein, 1993) and found it, and the type of workbench software of which it is a representative, to be applicable in all three types of curriculum orientations. We studied its cost-effectiveness, based on data acquired from a number of usage situations (Wetterling and Moonen, 1992), although here we found that the variety of procurement strategies and subsidizations accompanying EWB use in different countries precluded any definitive cost-effectiveness estimation (Wetterling *et al.*, 1992a). We observed its use in Dutch schools (Wetterling, 1991), and we analysed its potential for flexible and distance education, based on experiences with its use in The Netherlands, Scotland and Finland (Wetterling *et al.*, 1992b). As larger-scale activities, we studied its use in The Netherlands, in China, and in Bulgaria, in a variety of different types of schools and educational situations. The latter three investigations merit more detailed comment.

RESULTS FROM THE NETHERLANDS, CHINA, AND BULGARIA

The Dutch EWB study

The Dutch context for EWB use

The Dutch government has been explicitly stimulating the use of computers in schools since 1984. This support has paid particular attention to the vocational education sector. A particular teacher-training institute for vocational education was given a contract by the Ministry of Education to provide new instructional materials for basic electronics, including workbench-type software, to schools, and at the same time give in-service training concerning the use of the software to teachers involved in electronics instruction. To execute this approach the teacher-training institute acquired a license for the use of EWB in

The Netherlands and began preparation for a large-scale in-service programme around it.

In the period 1989 to 1991, the Ministry of Education of the Netherlands gave the teacher-training institute additional financial support for adaptation of the Canadian-originating package for better use in Dutch teacher training. For this adaptation, the teacher-training institute translated the help files of the EWB program into Dutch and constructed different graphic representations for some of the electronics symbols used in the software in order to better correspond to European notation. In addition, the teacher's documentation accompanying the package was translated into the Dutch language.

Using the adapted package, a series of 46 week-long in-service training sessions for teachers in higher vocational education was carried out. The courses were attended by over 500 teachers from approximately 100 secondary and vocational-education institutions from throughout The Netherlands. The cost to the teachers of attending the week-long course was 95 per cent-subsidized by a Ministry-supported agency. If a school wanted to use EWB, it had to send at least one teacher to the in-service course in order to acquire a school license for use of the software.

Procedure and subjects

In order to study the reaction of Dutch teachers and their students to the use of the EWB materials, a number of strategies were used. One of these was a questionnaire that was sent to 384 of the teachers that had attended the teacher-training sessions related to the EWB package. This questionnaire contained questions related to the teachers' subsequent use of EWB in their respective teaching settings; problems with hardware and software; perceived shortcomings relating to the content, user-interface and help-system of the package; the need for additional support for the use of the package; the fit of the package to the curriculum and training situation; the extent to which the package supplements or can even replace hands-on practice; and the costs of using EWB. Both fixed-option responses and open-ended responses were solicited. There was a response of 35.4 per cent to the questionnaire. Most of the respondents were teachers between the ages of 40 and 50 years old. They had relatively long teaching experience in electronics education

(the average was more than ten years). About half of the respondents were currently using EWB with their students.

Results of the Dutch survey

Full transcripts of responses and interviews are available from the authors on request (Collis, 1992). What follows is a summary with interpretive comments relative to different aspects of EWB that contribute to an examination of our hypothesis that workbench-type software is a good candidate for portability.

- *Flexible for different sorts of instructional settings.* The EWB package was used in a variety of ways in Dutch schools: both to illustrate theory and to support practical work. Often, the teacher used EWB as a demonstration package. Later, students did exercises, either alone or in small groups, while using the package. Students also worked independently with the package outside of regular class hours. The package was seen by some of the teachers as a supplement to and by others as a preparation for real laboratory work. Thus one of the important requirements for portable software – that it can be used in a variety of instructional formats – was supported by the ways Dutch teachers were using EWB.
- *Teachers' perception of educational value.* Another important component in educational software portability is that teachers in the receiving setting believe the software addresses real needs in their setting. The Dutch respondents were enthusiastic about the benefits of EWB use. For example, the Dutch respondents indicated they had observed the following benefits of EWB use in their own teaching:

Better running of practical experiences and experiments	86%
Good educational value	50%
Time savings	48%
Less assistance needed from teacher	47%
Less demand on facilities for experiments	42%
Cost savings	35%
- *Sensitivity to fact that the software originated in another country.* With respect to portability, the Dutch teachers' opinions about EWB were very good. There were no complaints from any of the

respondents related to the non-Dutch origin of the package (although the Dutch-translated help options and documentation and the Dutch teacher training undoubtedly contributed to this). However, the combination of a standard learning environment, cross-nationally recognizable, with the fact that its instructional adaptation rested with the teacher, not the software, supported the portability of this type of workbench software.

- *Curriculum fit of the package.* The Dutch respondents indicated that EWB fit best into the curriculum of beginning electronics instruction, with less success as students became older or more experienced. Interestingly, the package was often being used in subjects outside electronics, for example, mathematics, physics, general science, and also in specialist training areas such as 'digital techniques', 'telecommunications techniques' and 'technical measurement'. Thus, the workbench type of software appeared to be appropriate for a variety of curriculum areas, an important feature for heightening the portability potential of software.
- *Implementing the package.* In general, the Dutch teachers had little or no difficulty implementing EWB use on the computers available to them and their students. Schools frequently made their computer rooms available for EWB use and let students use the software in their free time in addition to during their classroom time, showing another way in which workbench software can extend the learning opportunities of the student while minimizing the need for extra instructor time. Also the package was often given to students to work with at home. All of these characteristics are important to portability (Collis and De Diana, 1990c).
- *Software features.* The respondents made many comments about the software itself. Some of these related to its content, others to its design. The comments showed a great diversity of opinion. By far the largest category of free-response comments made by the teachers was that of frustration over the fact that the software failed to offer various specialized electronics features available to the students in their regular laboratory practice. However, the teachers showed no real trend in what they felt should

also have been included in the simulated workbench, showing the degree to which instructors develop their own sense of what is important for practice and their expectation that instructional support materials should reflect this sense as closely as possible. This tendency remains a problem for workbench software, not only for its potential portability but even for locally developed products (see Bonekamp, 1991, and Rutten and Wong, 1991, for examples of the widespread range of opinion among Dutch electronics teachers as to what should be included in workbench simulations for electronics education).

- *Support and requirements for use.* A strong theme in the teachers' responses related to support they felt they needed for the use of EWB. Support was discussed in terms of the desirability of obtaining accompanying instructional materials for students with respect to their use of EWB, and in terms of the teachers having someone to turn to in case of difficulties with the software itself. Instructors commented on the lack of time available to them for the preparation of new student materials in order to make effective use of the software and indicated a desire for such materials to come bundled with the software. Also, teachers expressed frustration with the lack of local maintenance or technical support they felt to be available to them.

Both of the above categories of complaints will be intensified in the case of a workbench package being used in countries different from that in which it was developed and where a prior adaptation process such as occurred in The Netherlands with EWB has not occurred. Support materials for workbench software may be much more difficult to 'port' from country to country than the software itself, for reasons relating to language, background knowledge, and local curriculum (Ely, 1990). While the workbench software in itself functions as an 'open' learning environment, guidance material for students must of necessity be localized and specific. This is difficult for an external resource provider to achieve.

Also, finding local contact persons to supply up-to-date technical help with the software (and especially with new enhancements and versions) also becomes more difficult the further the software materials move from their place of origin.

This happened in the Dutch situation; teachers complained about various aspects of software performance when indeed these aspects had already been improved in newer versions of the EWB package in Canada. For various reasons, Dutch teachers did not hear about these improvements.

The Chinese EWB study

The context

Unlike the Dutch EWB study, which surveyed a wide range of teachers about their use of EWB, the Chinese EWB study involved the careful development of instructional materials for an examination of EWB potential in various Chinese educational settings. The changing climate in China is being accompanied by an increase in the use of computers in education (Zhongmin and Zhao, 1992) and by a growing pressure for the introduction of teaching innovations that stress active participation of students as well as more independent and creative thinking (Paine, 1992). Thus workbench-type software is already well positioned as a candidate for educational software portability with respect to powerful social and political factors in China. In addition, the teaching of electronics is a particular area of expansion for educational computing applications in China in that its teachers are among those already likely to have had prior experience with computers and also are among the relatively small number who have already engaged their students in different sorts of learning settings other than the still-dominant frontal-lecture type (Paine, 1992; Zhang and Collis, 1993).

The East China Normal University in Shanghai is one of the major settings in China for research and development in educational-computer applications. The chairperson of the Department of Modern Information Technologies in Education at ECNU (Prof Dong, one of the authors of this article), is a specialist in the area of simulation programs for electronic instruction as well as an electronics instructor herself. Thus ECNU became involved in an investigation of the portability of the Canadian-made workbench package EWB in China.

Procedure

The primary strategy for the evaluation of the

portability of the EWB package was within a particular course, 'Digital Logic Circuits', offered for students of the Department of Modern Information Technologies in Education at ECNU. This course ran from February through June 1992. Fourteen sets of lesson materials describing different circuit-building experiments were developed for the course, all to be carried out through the use of EWB instead of in the regular workbench environment. The experiments involved a variety of different types of uses of EWB, from review and reinforcement of previously learned concepts, to verification of the students' own hypotheses. There were 21 students in the course. Instructor and student experiences with EWB were fully annotated.

In addition, ten additional electronics instructors, from a variety of other types of educational institutions, were asked to use and evaluate the EWB package. A questionnaire was developed, which was filled in by the ten additional instructors as well as the instructor and the 21 students in the Digital Logic Circuit course (see Dong and Zhang, 1992, for the questionnaire). Based on the syntheses of these opinions and experiences, an evaluation of the portability potential of workbench software such as EWB in China was carried out (Dong and Collis, 1993).

Results

The following are main results of that evaluation:

- *Functionality of EWB for electronics instruction.* The Chinese respondents felt the EWB to be adequate in terms of the necessary instruments and parts that it offered for both analog and digital circuit experimentation. They felt the EWB to be an 'active' laboratory, where users were able to devise and adjust circuits that were true to the real case. They concluded that in many cases 'a well designed simulated laboratory is better than a real laboratory in that many more examples of correct concepts can be seen in a limited time' and that the careful analysis possible 'may not be convenient to do in the real circumstance of a laboratory experiment' (Dong and Collis, 1993, p. 4). However, the Chinese electronics instructors, like the Dutch, criticized the omission of various components in the simulated workbench.
- *Ease of use.* The Chinese respondents found the workbench package easy to use and appreciated

its help functions. They felt that one trial run was probably all that was necessary in order to use the workbench efficiently. The results of user actions were directly perceptible, important for independent use of a simulated workbench. The program was seen to be reliable. All of these factors are important for cross-national portability (Collis and De Diana, 1990c).

- *Implications of the non-Chinese origin.* Although the EWB package was used in its original English form in the Chinese evaluation, this was not seen to be a problem, given the age level and type of students who would be studying analog and digital electronic circuits in China. Few other aspects of the non-Chinese origin of the package were seen as troublesome for the Chinese respondents with the exceptions of (a) the fact that the printer function would not work for Chinese hardware, (b) that the copy-protection aspects of the software made it impossible to make any changes in the software itself or to use a package on different computers, and (c) that the costing policy (related to a national licensing system) would have to be modified in order to be realistic for Chinese budgets and distribution procedures. These are important issues for the cross-national portability of any type of educational software (Collis and De Diana, 1990c).
- *Educational benefits and flexibility.* The Chinese respondents were particularly positive over the fact that the workbench software allowed the teacher to prepare demonstration experiments and student materials in advance. They acknowledged that some time will be necessary for instructors to learn how to integrate this sort of software into their lesson planning, but were sure that in the long-run, the use of workbench packages such as EWB will save 'considerable trouble and at the same time get the same learning effect' (Dong and Collis, 1993, p. 5). Thus EWB in particular and workbench packages like EWB more generally were seen by the Chinese respondents as good candidates for use in China, regardless of the origin of the package.

The Bulgarian EWB study

The third of the special investigations into the portability of workbench packages such as EWB

took place in Bulgaria, under the leadership of one of the authors of this article, who was Director of the Research Centre for Educational Informatics in Bulgaria at the time of the EWB field investigation.

Context

Beginning in November 1991, five EWB packages were allocated to the following educational institutions: the Technical University of Sofia, the Experimental Secondary School for Electronics Technology in Sofia, the Vocational Secondary School in Electronics in Sofia, the Vocational Secondary School for Microprocessor Technology in Pravetz, and General Secondary School No 151 in Sofia. All the packages were installed at workstations in the computer laboratories of the schools, in order to analyse the possibilities for using EWB for teaching and learning purposes. The school teams responsible for the implementation and evaluation of the packages included highly qualified specialists in electronics and specialized teachers in the field. The EWB package was also evaluated by some independent experts from the fields of electronics, education, and educational software development (see Stanchev and Nikolov, 1993, for a full report).

Procedures

The package was used for teaching and learning various topics included in the existing curricula of the specialized schools (except for General School No 151, where it was used for extra-class activities). The teaching methods applied were as follows:

- the teacher demonstrated the EWB package while giving a lesson in order to visualize concepts in new aspects of the curriculum;
- the students' knowledge and skills in constructing electronic circuits were evaluated on the basis of how they used the EWB package;
- the EWB package was used as a tool for the integration and synthesis of basic concepts in a course in electronics;
- students compared and analysed the results obtained by using the simulated EWB laboratory with those they obtained from hands-on experiences in real electronics laboratories; and
- EWB was used as a tool by students for making the right choice of elements while designing a

circuit and while doing final projects for various courses.

Results

Because of the copy-protection system used on the EWB packages, the packages could not be tested in real classroom environments. None the less, the general opinion of all those who used the package was that it was very useful for specialized secondary schools and for the first courses in electronics at the university. The General Secondary School had a problem in that electronics is given minimal attention in its curriculum and thus students did not have adequate background knowledge about electronics to make much use of the workbench package. The students beyond the beginning level in university preferred a more sophisticated professional system for analog and digital simulations.

A number of positive conclusions were drawn as to the portability of the package:

- the interface is user-friendly;
- the package is relatively low in price compared to the costs of the equipment that it is simulating; and
- the package offers an easy and natural way of describing electronic circuits and applying test signals at a good performance speed.

However, a number of suggestions were made for ways to improve EWB's portability in the Bulgarian situation:

- tools for adapting the package to the students' native language should be included;
- the component libraries should be enriched;
- the copy protection used in the software is not appropriate for a school environment (the package supplied for the research could only run on a single computer);
- a networked version with distributed resources should be developed;
- mouse functions should also be assigned to keys; and
- some indications of the colours used in the screen displays should be given for those using monochrome monitors (Stanchev and Nikolov 1993).

All of these suggestions indicate the problem of anticipating a wide range of local hardware conditions when designing any type of software for cross-national use.

CONCLUSIONS RELATIVE TO THE PORTABILITY POTENTIAL OF WORKBENCH PACKAGES

Conclusions relative to the portability of workbench-type packages

Based on our various experiences with EWB, we feel convinced that workbench-type software is one of the most promising categories of educational software relative to portability potential. The reasons for this follow.

Technical considerations

- the necessary hardware does not need to be more than is typically already in place in secondary, vocational education and higher-education settings.

Educational factors

- the subjects for which workbench packages are most likely to be relevant (chemistry, computer techniques, electronics, for example) are reasonably likely to have similar concepts and curricula in different countries and settings; are being studied by older students for whom non-mother tongue software environments should be less of a problem; and have instructors with more-than-average prior experience with computer use;
- workbenches are flexible in application and can be used in a large variety of teaching and learning situations. The localizations will be done by the teacher through the way he or she uses the package, rather than being built electronically into the package; and
- user feedback can be visually given, via tables and graphs and meter-readings, thus minimizing issues with respect to cross-national differences in approach to educational interactions.

Social/cultural factors

- language used in the software itself can be minimized, thus avoiding not only translation and spacing issues but also issues related to cross-national differences in tone and style of educational communications (Kearsley, 1990; Murray-Lasso, 1990);
- there is a minimal chance of political or cultural issues impacting on the use of the software, as the subject areas involved are relatively culture-independent; and

- the teachers involved in the use of the workbench packages are already expected to be providing hands-on student activities so that less change is required in the role of the teacher than is involved in subject areas using more traditional, teacher-centred instruction.

Organizational issues

- the cost of the packages can be considerably lower than the cost of providing similar access to real analog and digital equipment; and
- the teachers who would potentially use the software are relatively easy to identify and, potentially, to target with in-service training.

Potential limitations to the portability of workbench packages

But, as our experiences with EWB have shown, workbench packages are not without their limitations relative to their likelihood of use in settings other than those in which they were developed. We have identified some major problems.

Simplicity vs adequacy

If the workbench is designed so that it is simple to use, this simplicity will have as its cost that the package does not include a full range of options. Many teachers will find the omission of various features unacceptable. (This appears to be the case, however, no matter how many options are included).

Feedback

A simulated 'workbench' (or 'toolkit' depending on which metaphor is more appropriate to the subject) needs to be open and flexible enough for a great many different types of learning activities to occur, but at the same time should offer some provision for immediate feedback with respect to the results of the user's experimentation. In workbenches for electronics instruction, feedback is provided by the readings on the various simulated measuring instruments, but for the learner with conceptual problems, more diagnostic feedback will probably be desirable. However, introducing meaningful feedback into an environment meant for free exploration is a substantial design problem.

Support materials

Accompanying print support materials that guide

the student (and teacher) in what he or she should do with the software environment are necessary. Instructional guidance should be built into the locally made support materials rather than into the software itself in order to best anticipate portability. However, this means that someone on the receiving end of the workbench package has to understand its potential well enough to construct local instructional materials that exploit the software's potential. This becomes more of a problem, the farther away the package goes from its developer. It also involves the local willingness to commit time and support to this materials-development activity, something not often factored into budget decisions relating to software licensing.

Visually oriented and language free

As much as possible, the software should be visually oriented and language free, to improve its likelihood of fit with a variety of levels of users and instructional purposes. However, visualizations are not necessarily culturally independent, and concern must be taken that symbols used are as meaningful as possible in different cultural settings. (See Lanzing, (1993a), for a literature study relating to the cross-cultural portability of visualizations in educational software.)

Hardware independent

Complex graphics are an integral part of workbench packages but increase the chance that the user may encounter hardware or printer difficulties when the software is ported. The software designer must anticipate that many users will have relatively simple hardware-printer combinations available to them but at the same time try not to limit the display power of the software, a formidable task.

On-line help

Tools for modifying on-line help options for the particular usage situation and mother tongue should be made available.

Costs

Cost considerations are still a major concern. Multiple-machine licensing and networked versions must be made available. This may end up as the final and most difficult barrier to cross-national portability – what the developer needs to

make a profit is more than many countries could even hope to pay, unless they have subsidization from some international agency. To our knowledge, this kind of large-scale national-level subsidization has not yet occurred.

To conclude

It is our belief that the portability of educational software is a critical global issue related not only to economic and market-growth considerations but also to human and moral considerations. Good instructional resources should be available for use in many different settings. However, the difficulties involved in adapting educational software for cross-national portability are complex and costly. Categories of software must be found that are most likely to be feasible candidates for portability and for uptake in target settings. We believe the category of software which we have called 'electronic workbenches' is highly promising in terms of its portability potential. Our experiences with various investigations of the portability of a particular workbench package, the EWB for electronics instruction, have in our belief supported our hypothesis. However, as our conclusions also show, care still needs to be taken and major issues resolved, even with workbench packages, before their cross-national portability potential will be realized.

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