

Portability and networked learning environments

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Abstract The portability of educational software is defined as the likelihood of software usage, with or without adaptation, in an educational environment different from that for which it was originally designed and produced. Barriers and research relevant to the portability of electronic learning resources are discussed and organised into a portability-limiting factors model. With the increase in number and scope of networked learning environments, portability issues take on a new dimension. Using electronic (study) books as an example, the portability problem space of networked learning environments is explored.

Keywords: Electronic books; Electronic learning resources; Networks; Portability.

Introduction

We define portability as the capacity of an item to be used in an environment different from that in which it was developed. With respect to educational materials, this means the likelihood with which a learning resource, developed in one context, can and will be used in other contexts, with or without adaptation. 'Context' can be defined in many ways, including ways that relate to curriculum, assumptions relative to didactic approach, level and purpose of instruction, characteristics of intended users, and also language and culture. In this paper, we first identify critical aspects of computer-related resource portability; next, describe a long-term research project investigating the portability of electronic learning resources in which we and a number of our colleagues are involved; and then indicate a new dimension for the portability research—the portability of networked learning environments. We conclude with an example of how we might apply our evolving overall perspective of the portability of electronic learning resources to the new problem space of networked learning environments by considering an example relating to 'electronic books' being made available through a network to multiple users for varying levels of transaction complexity.

Portability of educational materials - a research topic

There are important motivations for research aimed at increasing the portability of educational materials, relating to economic considerations, to the market for computer-related educational resources, and to issues of education and software engineering.

Economic and market motivations

Computer-related educational resources (for convenience, we will say electronic learning resources) are costly and time-consuming to develop. Thus there are practical and economic motivations for reusing or adapting existing materials, or components of materials.

Oliveira (1990) has noted three implications of portability for the overall market for educational resources: economies of scale, cost savings and cost effectiveness. Such issues are important; in their recent analysis of the market for electronic learning resources in The Netherlands, Van Deursen and Moonen (1991) note that despite extensive subsidisation and encouragement from the government over a five-year period, the market for electronic learning resources in The Netherlands is still weak.

Educational and scientific motivations

There are also strong educational and scientific reasons for research into the portability of electronic learning resources. From an educational perspective, we still have much to learn about effective design and implementation of such resources; we need to study the effects of the same or similar resources as they are used (or not used) in different contexts in order to understand better their fundamental implications for learning.

From the scientific perspective, there are important motivations for research into the portability of electronic learning resources. De Diana and de Vries (1990) note that users of educational software and courseware may wish to adapt a product in order that it may become more suitable, more effective, or more motivating. Adaptation should be possible in a 'frame of reference' that can be localised on one or more different levels of organisational complexity. Methodological principles stemming from software engineering — such as reusability, abstraction, and hiding — are features likely to support the development of more adaptable and thus more portable products.

Reusability

Reusability involves using existing parts of products for the development of new products. As a consequence, it involves a developmental approach in which products are designed in such a way that their comprising parts could be reused in future products. Developing products in a reusability-oriented approach can result in component banks, such as object-libraries in object-oriented programming environments. From the perspective of portability,

the availability of such partial products could be a convenient way to support product modification.

Abstraction

The principle of product abstraction involves a differentiation between generic and specific aspects of a product architecture and can be applied in educational software products in a threefold way (De Diana, 1988). In the first place, a distinction has to be made between the conceptual product structure to be used for product realisation (such as a hierarchical structure or an object-oriented structure) and the actual structure used for product implementation. We consider portable products to be clearly structured products.

In the second place, a distinction has to be made between the product structure and the programs that are embedded in this structure that bring about the interaction between learner and computer. Thus, products are to be preferred that allow for program modification without structure modification.

In the third place, educational software and courseware usually involve the use of educational data such as instructional text and graphics. Portability usually involves a product adaptation in order to exchange such data with more appropriate local or national data, for instance the replacement of English text with Spanish text. Portable products call for the possibility of making such replacements without modifying either the product structure or the modules of programs.

Hiding

The principle of hiding is concerned with efficiency in controlling the quantity of information in such a way that only task-relevant information is presented. The implications of this principle for portability involve locating specific modules, that can be accessed for adaptation purposes, in such a way that changes do not effect other parts of the product.

Barriers to the portability of electronic learning resources

Despite the importance of increasing the portability of electronic learning resources, portability is limited by many barriers. Any one of a number of factors can become critical enough to prevent use of a resource outside of its developer's context. These factors can be categorised as:

- a) technical factors;
- b) educational factors;
- c) social/cultural factors, and
- d) organisational factors (see Collis & De Diana, 1990, pp. 7-8, for an elaboration).

In different educational contexts, these factors interrelate in different ways. Strategies to minimise the negative impact of the factors on resource portability are the object of research in many different settings and institutions (for example, Dahlstrand, 1984; FUNDESCO, 1990; International Standards Organization, 1982; Ministry of Education Ontario, 1987; Murray-Lasso, 1989; Nicklin, 1990; Sandford, 1989).

Research on the portability of electronic learning resources

A long-term research project at the University of Twente relates to the portability of computer-related educational resources. Our research involves:

- technical issues of software portability;
- design issues related to increased adaptability;
- educational issues of flexibility for curricula and didactic reasons;
- social and cultural issues affecting portability;
- issues concerning production efficiency, cost, distribution, dissemination and policy.

As part of the research we are regularly revising a general model for the portability of electronic learning resources, testing the model through research and analysis, and revising the model again.

Our overall research also involves the synthesis of a number of component research projects. Some of these relate to the portability of software products; others to the distribution mode of electronic resources as an aspect of portability.

For example, in the 'product' category, Mols has investigated the portability of several non-complex pieces of educational software in terms of their adaptation for use in Mexican schools (Mols, 1991a,b). Another project, involving the impact of visualisation in educational software on the cultural portability of the software, is completed and featured field work in Bulgaria (Lanzing, 1991). The 'Electronic Workbench Study' has investigated the portability of a particular simulation package for electronics instruction (Collis *et al.*, 1992; Wetterling *et al.*, 1993). Furthermore, an in-depth investigation of the portability of authoring environments (see De Diana, 1988) for educational software has begun in China (Zhu, 1991) and features redesign for portability.

But our interests also relate to the distribution modes for electronic learning resources, modes which in themselves may be either human or electronic. A research activity involving a shared hardware-software environment in China is one project with this orientation. Zhu and De Diana (1993) and Zhang Ji-Ping and De Diana (1990, 1991) have described some software product architectural issues involved in this research.

Finally, we are now involved in the exploration of telecommunications as an electronic learning environment where portability is a base-line condition as, by definition, components of such a system are in different physical contexts from each other (Heeren & Collis, 1993).

We see our work as evolving in two important dimensions: from electronic products to those products as made available through an electronic distribution mode; and from the perspective of the 'transfer' of a product from 'a' to 'b' to the perspective of 'sharing' electronic learning resources among various sites and users. The latter perspective includes two-way (or multi-way) interaction within electronically networked learning environments. In the remainder of this paper we will look more closely at this research area of portability related to electronically-networked learning environments.

Conceptualisation of the problem space

Studying the implications of sharing learning resources when learners, teachers, and learning resources are physically distant from each other is not new, as it has long been a major part of the problem space for designers of resources for use in distance education (see Potter, 1990, for a helpful analysis). Also, the idea of two or more users sharing the same software resource is not new either, as the literature in the area of computer-supported cooperative work (CSCW) attests (see, for example, Greif, 1988).

However, the combination of computer and telecommunications technology with the concepts involved in distance education with regard to distributed sharing of resources and distributed communication, and with new concepts such as 'telecooperation' (Heeren & Collis, 1993) can be seen as an important new area for portability considerations.

We can conceptualise the problem space for the portability of networked learning environments as involving (at least) two dimensions — one which relates to the complexity of the educational transactions occurring through mediation of some kind of network, and a second which relates to the complexity of the various different educational, institutional, cultural, and social contexts in which the shared transactions take place.

With respect to complexity of interactions, we are working now with a simple three-level view (where the levels are 'sharing a resource', 'communicating', and 'problem solving') recognising that the dynamics of 'cooperative work' are complex even without distances separating the co-workers (Holand & Danielsen, 1991; McGrath, 1990). Bannon and Schmidt (1991), for example, see the core requirements of CSCW as mediating and coordinating the association of the individuals involved, supporting a shared information space, and designing socio-technical systems in which the CSCW takes place and is validated. Thus we expect more refinement of this 'Complexity of Transactions' dimension as our work proceeds.

With respect to the second dimension, 'Complexity of Participant Distance' (or, shorter, 'Distance Complexity') we suggest four such distance-related contexts in which educational resources can be shared electronically: sharing within the same educational unit such as a school or department in a university (for example, through a local-area network); sharing within the same educational jurisdiction but involving different units (such as networking throughout a university or a school district); sharing within the

same language or cultural reference group but outside of one's region (such as with other schools in one's country or other universities); and finally sharing across language and cultural borders (as is the case in international telecommunications activities, see Collis, 1991b, and Collis & de Vries, 1994, for overviews of European-wide projects of this sort).

This conceptualisation suggests the following matrix of the problem space for the portability of networked learning resources, Fig. 1, where we include coordinates to facilitate subsequent discussion of the cells in the matrix.

Complexity of distances separating participants:				
Complexity of transactions:	LAN	Within-region	National	International
Sharing a resource:	1,1	1,2	1,3	1,4
Communicating:	2,1	2,2	2,3	2,4
Problem-Solving:	3,1	3,2	3,3	3,4

Fig. 1. Problem space related to the portability of networked learning

Some examples of the sorts of situations we are considering are: students within a course making common reference to course material stored on the file server of a LAN (Cell 1,1); participants in a regionally-based training program interacting electronically in a group discussion about training issues while staying in their workplaces (Cell 2,2); and scientists in a number of countries working together on a common problem (Cell 3,4).

The development of materials to support and stimulate learning, communicating, and problem solving in more-and-more complex distributed learning communities is clearly going to involve portability considerations.

Initial Analysis of 'Hot Spots' in the Matrix

It can be seen that at each level of physical separation from one another, there is increasing likelihood that sharers of the system come from different educational backgrounds and settings, use the system for different educational purposes, and even speak different languages. Thus the number of factors which can contribute to portability difficulties increases as the distances involved increase, with Column 1 cells as least problematic and Column 4 cells as most troublesome. Over each distance-level we see potential portability problems with respect to each of the sets of factors — technical, educational, organisational, and social-cultural — that we have been investigating in the overall portability research. Similarly, the more complex the interaction that must be facilitated, the more sophisticated our learning environment must become, with difficulty increasing as we move from Row 1 to Row 3. By extension, we expect Cell 1,1 to be least complex

and Cell 3,4 most challenging. We shall digress for a moment to summarise these factors, or 'hot spots', as described from the point of view of the instructor considering the use of software originating from somewhere else.

It is clear that this instructor may be frustrated if:

- 1 the program's architecture is rigid and thus cannot be modified;
- 2 the product does not fit the local curriculum (and again, cannot be efficiently modified so that a better fit can be obtained);
- 3 a certain classroom environment appears to be presumed and this environment is different from that available to the teacher;
- 4 the teacher and students are not able to work in their mother tongue;
- 5 certain cultural assumptions or orientations permeate the software that are inappropriate to the new setting;
- 6 local institutional procedures for decision making about software acquisition, distribution, and support are ineffective, or
- 7 ownership issues make it difficult for the teacher and his or her school to obtain promising software even if it is appropriate or easily modifiable.

(from De Diana & Collis, 1990, p. 337).

We will consider these 'hotspots' using an electronic study book example. How does shared use of a networked learning environment make portability issues relating to electronic books more difficult, even while it offers new educational possibilities?

Portability considerations of Electronic Study Books

The Electronic Study Book in portability problem space

The concepts of electronic books (Barker, 1990; Barker & Manji, 1989) and electronic study book platforms (De Diana, 1991) are being increasingly discussed in the literature. The electronic book can be conceived of as an extension to or even a successor of the paper book. The electronic study book can be conceived of as an electronic book, enriched with study facilities; a multi-media document enriched with cognitive study-support tools such as information marking, and support for group-based learning (De Diana, 1991). Electronic study book platforms relate to the environment of book use. It is expected that electronic study books will prove to be of particular use if they are available in networked learning environments in which groups of learners can share information and work in a cooperative way (Collis, 1991a). In such an environment, supportive software tools linkable to the electronic study book are to play an important role (Barker, 1992).

The users of electronic study books should be able to call upon software tools to help them:

- to analyse and process information contained in the books. In our matrix, these tools probably relate to the cells in Row 1, 'Sharing Resources'.
- to communicate with other users, for instance about problems and exercises related to the book. In our matrix, these tools probably relate to the cells in Row 2, 'Communicating'.
- to store and retrieve various kinds of additional documentation that is related to the use of the electronic book. In our matrix, these tools can relate to all three rows of learning-transaction complexity, depending on how much different users are communicating with each other about the electronic book or using the electronic book as a resource for a problem-solving task.

We will now continue with our exercise of relating the use of electronic (study) books to the problem space for portability and networked learning environments. We organise our discussion around the columns of the complexity matrix.

Distance complexity 1: the LAN

The LAN column, Cells 1,1 through 3,1, is the least problematic of the distance levels from a portability perspective. At this level, the electronic (study) book platform is hosted upon a LAN and all users of the electronic (study) book can share in the same hardware and software environment. Furthermore, it is likely that these users share a common educational culture, language, frame of reference, etc. Some hot spots might cause problems, such as Item 1 (Program's architecture is rigid and thus cannot be modified) and Item 6 (Local institutional procedures for decision making about software acquisition, distribution, and support are ineffective). Typical sources of portability problems are to be expected from rigid electronic book architectures that cannot be modified by book users, and from inefficient and poorly coordinated institutional organisation of book use (Collis, 1991a). Whereas the first type of problem can be solved by technical types of solutions, the second type clearly is of a (human) organisational nature.

Distance complexity 2: within-region

The within-region column, Cells 1,2 through 3,2, offers a situation comparable in many ways to that of the LAN column. The within-region environment could be comprised of several LANs linked together, forming a regional WAN. Within the regional WAN, the use platform is likely to be hosted upon compatible (or even identical) hardware and software, thus removing many of the technical-compatibility problems. However, we presume that the problems that have been mentioned for the LAN portability problem space are also to be encountered in the within-region space. Additional problems can be expected as well, for example, related to

the 'hot spot' Items 2, 3, and 7. Item 2 ('The product does not fit the local curriculum and cannot be efficiently modified so that a better fit can be obtained') might cause problems if the within-region area is comprised of various types of educational institutions that differ, for instance, in educational level. Differences between levels of education might result in incompatibility of study goals and thus might block common use, even in a within-region network, of the same electronic (study) book. It might be expected that different versions of the book will result.

Hot Spot Item 3 ('The presumption of a certain classroom environment and this environment is different from that available to the teacher') might manifest itself in another form in the within-region column. Available software tools and conditions of software use might differ to such a degree that teachers and learners might not 'feel at home' connected to the networked learning environment.

Hot Spot Item 7, ('Ownership issues that make it difficult for a teacher and his or her school to obtain promising software'), might manifest itself in the within-region space as well. One of the participating LANs might have bought software for its own use, but is not comfortable with it being accessible by the other LANs as these LANs did not pay for it and its use therefore may not be allowed for legal reasons.

Distance complexity 3 and 4: national and international

Between the within-region space and the national and international spaces the conditions of networked learning might change drastically, at all three levels of transactional complexity. When within-region networks are coupled into an overall national or international network, there might be large differences in the characteristics of hardware and software in the various local or within-region networks.

Thus the portability of electronic (study) books could be limited by technical factors. Hot Spot Item 1, ('The program's architecture is rigid and cannot be modified'), could seriously amplify this type of portability problem. Furthermore, even on the national level, we could encounter difficulties stemming from the Hot Spot Items 4 and 5, involving cultural and language differences.

In extension, we expect the international problem space (Column 4) to include a combination of all the kinds of portability problems discussed so far in respect to networked learning environments across LANs, regional WANs, and national networks. However, at the international level, language-related, cultural, jurisdictional, distributional, and political factors will also confound the complexity of the portability problem space.

Complexity of learning transactions

In the above analysis, we have focussed on one dimension of the portability problem space for networked learning environments: the dimension relating to complexity of the distance between the interacting components. We can

make a similar analysis based on the rows of the problem-space matrix, where the complexity of learning transactions is the focus. Each of the three rows: sharing resources, communicating, solving problems cooperatively: is progressively more complex to organise and support, even in traditional instructional settings. We have hardly begun to consider models for effective networked learning environments for these three levels of transactional complexity, even within the least complicated user-relationship setting (the LAN). We have far to go in specifying effective instruction when more complicated distances are involved between actors, for each level of transactional complexity.

Solution directions for the portability problem space

In the context of our discussion of the overall portability problem space for electronic learning resources, we have suggested solution directions that are likely to improve the chance of portable courseware products (De Diana & Collis, 1990). We believe this list to be equally applicable to networked electronic learning resources. We conclude this article with a list of some of our suggested directions for improving portability of any sort of electronic learning resource:

- 1 Courseware products should have a modifiable architecture.
- 2 Products should be able to fit or to be tuneable to local curriculum and conditions.
- 3 Differences in learning-environment atmosphere must be reckoned with. (The concept of 'classroom environment' may be exchanged for the concept of electronic study platform in networked learning environments.)
- 4 Courseware products should be modifiable in order to let students and teachers work in their mother tongue and with the type of visualisation and example most appropriate for them.
- 5 Courseware should be designed and developed without, preferably, strong cultural assumptions or orientations.
- 6 Electronic learning environments need a sound organisational structure.
- 7 Electronic resource ownership issues must be taken seriously.

Conclusion

The portability of educational resources such as software and courseware is a major constraint on the dissemination and improvement of electronic learning, from economic, scientific, and educational perspectives. Barriers to the portability of electronic learning resources are numerous, but can be grouped into clusters of factors. Within the setting of networked learning environments, the portability of educational resources is becoming a matter of serious concern. A list of solution directions has been offered; now it is our task to examine them empirically in the context of networked learning.

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