Educational Software and Learning: Subversive Use and Volatile Design

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Abstract

Discussions about the use of information and communications technology (ICT) based learning environments often assume that use is defined, or at least severely constrained, by the inherent intentions of the designer. However, typical uses of educational software involve a subversion of the designer's intentions to match contextual needs. Designers should consider designing for subversive use, recognising that users fit the use of ICT environments into contextually tuned 'situated' learning environments. In this sense, good design is volatile design, i.e. design which changes with contextual use. These ideas are illustrated with reference to a range of ICT learning environments.

1. Introduction

It is often assumed that the use of information and communications technology (ICT) based learning environments is dictated by the inherent intentions of the designer. However, the fundamental assumptions of contemporary constructivist views of learning run counter to this assumption. A tenet of constructivism is that learning is a personal idiosyncratic experience, characterised by individuals developing knowledge and understanding by forming and refining concepts [1]. The focus of constructivism is on learner control, with learner's making decisions which match their own cognitive state and their own needs. Thus we are left with a paradox if a we accept a constructivist view of learning: In trying to design effective learning environments we may at the same time constrain the levels of freedom necessary for learners to make decisions about their own learning.

There are two possible solutions to this paradox. First, educational users of ICT can subvert the design of software to meet their own needs, i.e. through the way in which they use software, teachers and learners can recast the designer's intentions. From a design perspective I call this 'delegated subversion'. This delegation can happen at three levels, depending upon whether the software incorporates explicit, implicit or absent educational design intentions. Subversive use of software in the first category will require a conscious attempt to thwart the intentions of the designers. In the second case software may be used subversively without the user being aware of it. In the third case, by definition, an absence of underpinning educational design intentions - often due to software originally intended for non-educational use being 'hijacked' for educational purposes - puts the onus on the teacher and/or leaner to subvert the designer's non-educational intentions.

The second solution is to recognise the essentially subversive nature of the educational use of ICT and deliberately design for such use. Rather than design with constraint in mind, design with freedom and flexibility in mind. From a design perspective I call this 'incorporated subversion'. This emphasises the active and purposeful role of learners in configuring learning environments to resonate with their own needs, echoing the notions of learning *with* technology through 'mindful engagement' [2] and learners as designers trying to represent their own knowledge [3]. Incorporated subversion leads to software designs which are volatile in nature, responding to the changing and idiosyncratic needs of learners.

A synthesis of the essential features of a constructivist view of learning should (i) illuminate the characteristics of delegated subversion and (ii) provide guidelines for designing applications which feature incorporated subversion.

2. Constructivist theories of learning and educational software design

As theories of learning have developed and educationalists have gained more experience of using computer based technology, there has been a shift of emphasis from the behaviourist paradigm, through the weak artificial intelligence approach, to a constructivist view. The behaviourist paradigm dominated early notions of computer assisted learning, e.g. the large scale drill and practice systems for mathematics developed at Stanford University [4], and much software conforming to this paradigm is still produced, e.g. integrated learning systems. During the 1980s developments in artificial intelligence spawned the concept of intelligent tutoring systems. Attempts to

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produce these systems assumed that it is possible to develop accurate and meaningful models of the learner and teacher. However, the development of credible learner and teacher models has proved intractable, and to all intents and purposes the weak artificial intelligence approach has been discontinued. For most educationalists constructivism offers far more scope for realising possible learning benefits of using ICT. In fact Reeves [5] refers to the claim by Gagne and Glaser [6] that virtually all self-respecting instructional design theorists now claim to be cognitivists.

Many writers have expressed their hope that constructivism will lead to better educational software and better learning [e.g. 7, 8, 9]. They stress the need for open ended exploratory authentic learning environments in which learners can develop personally meaningful and transferable knowledge and understanding. The lead provided by these writers has resulted in:

- the proposition of guidelines and criteria for the development of constructivist software [10, 11, 12, 13, 14, 15, 16, 17, 18]
- the development of interactive learning environments based on constructivist principles, e.g. the role playing simulations (*Lake Iluka* and *Exploring the Nardoo*) developed by the Interactive Multimedia Learning Laboratory at the University of Wollongong and the *Jasper Woodbury Series* developed by the Cognition and Technology Group at Vanderbilt University.
- suggestions for the constructivist use of modern ICT systems such as the World Wide Web [e.g. 19]
- the identification of new pedagogies [20, 21]

A recurrent theme of these guidelines, software developments and suggestions for use is that learning should be *authentic*. This notion of authenticity can be considered from both cognitive and contextual perspectives.

2.1. Cognitive authenticity

Authentic learning experiences are those in which learners are assisted in some way to construct and refine concepts in personally meaningful ways. In such environments some or all of the following situations and conditions apply:

- Opportunities are provided for the learner to explore the behaviour of systems, environments or artefacts, e.g. simulations. The environment provides the learner with intrinsic feedback which represents the effects of the learner's action on the system, environment or artefact.
- The learner is able to express personal ideas and opinions, with the environment providing a mechanism for the articulation of these ideas. Papert has described computer based microworlds acting in this way as 'incubators of knowledge' [8, 22].
- Learners should be able to experiment with ideas and try out different solutions to problems. In this sense they should be able to adopt multiple perspectives by engaging in activities which support multiple knowledge representations, experience varied cases and contexts, and have varied purposes for knowledge. Using analogies and extension [23] and constructionism [24] are relevant here.
- A sense of ownership should be a prominent feature of learning. Learners need to be encouraged to take responsibility for learning. Strategies for encouraging metacognition and intentional learning are relevant here [25].
- Learners should be presented with complex environments which are representative of interesting and motivating tasks, rather than contrived sterile problems [14].
- Learners may need help in coping with complexity. Strategies to help learners include scaffolding [26], anchoring [23] and problem based environments [27, 28]

2.2. Contextual authenticity

It is now commonly advocated that cognition and learning are situated in specific learning contexts [7, 29, 30]. A situated view of learning implies that effects on learning of using ICT will depend on the context in which it is used, with all the components of a learning environment (people and artefacts) interacting and contributing to the learning process. Some writers, e.g. Pea [30], see 'intelligence' in a given context as distributed between people and ICT applications. Clearly a critical feature of any learning environment will be the role played by the teacher, and many educationalists now believe that a very important role for educational software is to foster a move from teacher centred to leaner centred pedagogies.

A belief in contextualised learning has the following implications:

- The situated nature of knowledge implies that learning environments should relate to personal experience of the real world.
- The distributed nature of intelligence implies that learning is best supported when technology augments learning rather than attempting to supplant it [31].
- Collaborative learning in which peer group discussion and work is prominent is effective in helping students to learn [32, 33].
- The role of the teacher will change to a manager and facilitator of learning, rather than a director [34].

3. Delegated subversion and design

The concept of contextual authenticity is crucial in understanding the notion of delegated subversion. A belief in situated cognition leads logically to a belief that design will always be contextually re-interpreted to some extent. In particular the social context may provide opportunities for expression through peer discussion and group work, and the resource context may provide opportunities for exploration by making additional linked learning materials available.

3.1. Examples of delegated subversion

Conscious attempts to thwart designers' intentions are illustrated by the imaginative use of simple drill and practice programs. For example, a program intended to teach the names and locations of state capital cities might present learners with a map of the USA and invite them to select the name of a city from a menu for each marked location on the map. From a constructivist perspective the isolated use of this program would be regarded as a poor learning experience. However, the intended use could be subverted by linking an initial use of the program to problems which involved the use of a paper based atlas or searching the World Wide Web. In this way the behaviourist design of the program would be assimilated within a broader constructivist framework by providing linked resource materials.

World Wide Web based activities provide examples of the delegated subversion of implicit educational design features. Educational materials available on the Web may be designed with clear educational aims, but the global context of the Web means that Web pages may be 'acquired' and used by other users who are unaware of the original design intentions.

The significance of delegated subversion in both social and resource contexts is evident in more imaginative uses of adventure games in classroom settings. While the individual use of such games may provide problem solving and decision making experiences, much of the learning potential for these environments is realised when learners engage in related 'off-computer' activities. e.g. writing stories, drawing pictures, and acting in role playing exercises. The use of *The Oregon Trail* simulation illustrates this:

> For example, teachers using the popular simulation The Oregon Trail, which puts students into the role of early pioneers, have incorporated subject areas beyond social studies: language arts (having students keep journals); mathematics (in planning purchases for the trip); art (making maps and drawings for the walls illustrating the journey); science (learning about climate, wildlife, and nutrition during the trip), and music (singing songs of the pioneer days). [35, p. 95]

The use of generic software tools in an educational context provide more examples of delegated subversion. Such tools were not designed with learning in mind; rather their design is intended to facilitate well defined common tasks in industry and commerce. However, the use of such applications as word processors and spreadsheets to support learning is now common. In order to match learning goals, these applications are often customised, e.g. spreadsheet macros and templates are provided.

4. Incorporated subversion and design

The twin notions of cognitive and contextual authenticity imply that learners should have opportunities to work in environments which allow for idiosyncratic exploration and expression. Opportunities for exploration without opportunities for personal expression lead to learning experiences which are limited by the designer, and thus lack personal significance. Expression without exploration provides no opportunity for testing and refining concepts. Thus design which features incorporated subversion needs to address a need for synergistic exploration and expression. A crucial feature of incorporated subversion is the creation of a link between exploration and expression by providing intrinsic feedback representing the effects of learners' actions.

The notion introduced by Norman of the designer's model of the learner's model [36] is useful in this context. Norman acknowledged the existence of the designer's model as a conceptual model of the ICT system, and the learner's model as the user's mental model of the target system. He also described the designer's model of the learner's model as:

> [...] we need a conceptual model of the system: call the conceptual model of *t*, *C(t)*. And now let the user's mental model of that target system be called *M(t)*. We must distinguish between our conceptualisation of a mental model, *C(M(t))*, and the actual mental model that we think a person might have, *M(t)*. [36 p.11]

In this sense the designer must have a well formed model of the learner's model of the software environment, so as to craft cognitively significant feedback mechanisms. The features of constructivist learning previously described should provide a framework for this design task.

4.1. Examples of incorporated subversion

The August 1996 edition of *Communications of the ACM* included a section entitled 'Using Computational Media to Facilitate Learning'. In the introduction to this section the guest editors state:

> The following articles describe how computational media can be used to provide just such rich, explorative, constructive learning environments [...]. Learners have the

> opportunity to directly experience otherwise abstract notions. Moreover, reconstructable and multiformatted computational media uniquely enable designers to better craft these environments to address the special needs of learners. [37, p. 83]

The phraseology adopted by the editors indicates an implicit belief in incorporated subversion as a design aim: notions of exploration and expression are evident in the terms ‘explorative’ and ‘constructive’ respectively, and the close juxtaposition of these terms implies a desire to link exploration and expression. Given these strong implications of incorporated subversion, the descriptions of the nine software environments described in the section should provide a context in which to assess how designers can incorporate subversion in design.

The focus of the first set of articles is on modelling the real world, with the underlying assumption that links with the real world will provide contextual legitimacy, and that the process of modelling will provide a mechanism for personal expression. The modelling activities described are: using learner shot video as data for mathematical analyses, investigating and modelling phenomena using mathematical functions with the aid of a software function ‘probe’, using visual iconic representations for mathematical modelling, using interactive video to measure the characteristics of motion, and exploring change through simulations. The second set of articles deals with software environments that enable students to manipulate multiple representations. This second set deals with multiple space and time levels in genetics, human-computer collaborative learning associated with understanding electoral systems, and the development of literacy. I will choose two examples from each set to illustrate my assertions about incorporated subversion: video based labs and functions machines as examples of modelling, and understanding electoral systems and the development of literacy as examples of multiple representations.

4.1.1. Video based labs. Rubin, Bresnahan, and Duca [38] introduce the notion of video based labs as a general description of the use of learner shot video as a basis for mathematical analyses. They describe how learners ‘explore and analyse their own experiences by making measurements on videos of real phenomena’. Specifically they claim that:

> Video allows them to slow down or speed up time; associated computer tools let them analyse events they have actually observed. By making measurements on a single frame of video, students can explore the “fine structure” of actions that take place quickly, like bouncing balls or flying paper airplanes. They can examine patterns of motion through the video analysis of their own bodies in such activities as sport and dance.’ [38, p. 84]

Rubin et al. illustrate their claims by describing how two girls used *CamMotion*, an example of a video lab system, to explore a dance sequence performed by one of the girls. Temporal and spatial data were collected by clicking on points on the moving body during the videoed dance sequence. The data so obtained were imported into a spreadsheet to facilitate graphical analysis.

Even such a conceptually simple use of technology to support learning can be seen as an example of how to incorporate subversion in design. Video is used to provide real world contexts chosen by the learner as being of relevance and interest to their own learning. The features of interactive video presentation are used to facilitate open ended exploration: learners are in a position to decide what features to investigate and what methods to adopt. The computational power of the computer, delivered through such applications as a spreadsheet, enables learners to analyse data in ways decided by themselves, thus providing intrinsic task focused feedback tuned to their own problem solving concerns.

4.1.2. Function machines. Feurzeig and Richards [39] describe a modelling environment based on the central metaphor of function, e.g. procedure or algorithm, represented as a machine. Each machine is displayed as an icon with inputs and outputs. Learners can get a machine to pass data and control outputs to another machine by drawing links between machines. Collections of connected machines can be represented by a composite icon. Machines corresponded to basic operations typically found in standard languages are provided as primitives.

The *Function Machines* system described above is a very different modelling environment from the *CamMotion* system. The link with real world experience is far more tenuous. Incorporated subversion is evident in the way learners are afforded opportunities to construct explanations in terms of their definitions of the role and function of objects and the relationships between the objects.

4.1.3. Multimedia literacy materials. The *Little Planet Literacy Series* is described as a learner centred multimedia language and literacy program for beginning readers [40]. The series consists of two video anchor stories. Three claims are made for the use of the videos. First, community building is fostered by the visual support the videos provide to develop shared understanding and vocabulary. Second, conceptual richness is offered through the complex and dense narrative afforded by the video presentation. Placing the videos on computer controlled CD-ROM allows non-readers and early readers to control their exploration of the narratives. Third, extended knowledge building is fostered by the intrinsic motivation of the video format.

Specific anchor activities are suggested. Children are encouraged to discuss and order pictures form the anchor story. This can be done using a variety of representations. The pictures can be ordered physically by using laminated cards, or with the assistance of software. This software enables them to place the pictures in any order. If the children do not remember the part of the story the picture corresponds to they can click to revisit a video scene or ask for an audio clue. A multimedia storybook maker is also available. The description by the Cognition and Technology Group of the use of this feature clearly indicates the multiple representations afforded by the environment:

- Pictures from the sequencing activity help construct a book in the child's own words.
- The Movie button turns the still picture into a dynamic clip from the story, providing a powerful retrieval tool.
- The Record button enables children to orally narrate the story.
- The Words button helps students sound out words and turn their recordings into print.
- The Music button allows children to select from a variety of musical clips to best fit the emotional tone of each page
- The Play button lets children see and hear the pictures, their recorded voices, printed words, and selected music.
- When all pages are completed, the book is printed out. A videotape of the multimedia book can also be made. However, the children especially love the books and take them home to share with their families.[40]

Clearly learners are provided with multiple representations in both exploratory and expressive contexts. Of particular note is the way in which multiple forms of expression in the composition of stories. Taken together with the capacity provided for the students to produce a story based on their own sequencing, this amounts to an example of incorporated subversion aimed at recognising learners' needs to reflect their own preferences in exploration and expression.

4.1.4. People Power. Dillenbourg and Self [41] claim using *People Power* will help learners discover which features make an electoral system more or less proportional. They state that 'The learner can design an electoral system by defining parties, candidates, constituencies, and so forth. The learner can also modify the electoral rules, run a simulation of the elections, and read results of elections' (p. 104). A game based on gerrymandering is also included, with the aim of the computer acting as a co-learner with the learner. Dillenbourg and Self claim that the 'learning mechanism is not inspired by traditional machine learning techniques, but by psychological theories concerning the influence of social interactions on individual development' (p. 104).

The software affords learners with opportunities for constructing their own electoral scenarios, and of playing out the consequences of their decisions while collaborating with a machine based co-learner. In this way they have the opportunity to see how their expressions may be interpreted in different ways. This provides intrinsic feedback to learners, thus providing a way of helping them to cope with the complex environment resulting from their construction of a simulated electoral system.

5. Conclusion

The discussion of constructivist design features indicates the need for designers to recognise that the use of the software they design will be determined by the way their assumptions are interpreted in varying educational contexts. This implies a subversive role for both teachers and learners, in which they re-interpret design intentions to suit their particular needs. This paper proposes that while this subversive role can be delegated to teachers and learners, a more principled approach is to actively incorporate subversion into design. In this sense designs become inherently volatile, providing environments which can be tuned to the idiosyncratic needs of learners..

There are specific deign approaches incorporating subversion. As the *CamMotion* software demonstrates, linking to personal real world experience is one way of providing this support. Another way is to link expression to the structure of the environment itself - *Function Machines* provides an example of this approach. The use of rich environments which offer multiple representations, as illustrated by the Vanderbilt multimedia literacy materials and the *People Power* software, is another approach. An emphasis on learner construction of computational artefacts, as in the

Function Machines software and the Vanderbilt materials, is a major design criterion.

If the use of educational software is to realise its full potential, designers need to be aware of such approaches and consider using them as a basis for volatile design.

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