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# Emergent complexity in learning and teaching by combining simple learning technologies.

John Rosbottom & Jonathan Crellin

University of Portsmouth  
Department of Information Systems and Computer Applications  
Burnaby Terrace, 1 – 8 Burnaby Road  
Portsmouth, PO1 3AE, UK  
*Contact:* [john.rosbottom@port.ac.uk](mailto:john.rosbottom@port.ac.uk)

## Abstract

*What are the advantages and disadvantages of a monolithic virtual learning environment compared with a more diverse assembly of software elements adapted for learning? Is the whole greater than the sum of the parts when simple learning technologies are utilised in combination? Can a rich, relatively complex, learning environment emerge from a combination of relatively simple, individual learning elements?*

*These questions are addressed in this paper, and we describe some of the outcomes we have observed when students use a learning environment developed using a number of loosely related web technologies together with more traditional teaching methods.*

*Our strategy for the development of teaching and learning is to combine well understood tools involving a website, web forms, audio and video tools and RSS to produce an interactive learning system that can be taken in various directions depending on the needs and interests of the learners and the teacher.*

*We believe that combining these simple elements can produce a learning environment that is robust, maintainable, controllable and is tuned to the needs of the students and the teachers. Our approach encourages experimentation, keeping what works and easily discarding what is unsuccessful or requiring further development.*

*This paper describes the continuing evolution of our approach, and the reactions of learners. We compare our approach based on the use of simple tools with development using a virtual learning environment (VLE).*

*The paper addresses the conference theme of enhancing the scope of technologies beyond their usual application limits.*

## 1. Background

As a University we at Portsmouth have a few distance learning courses involving remote students who never attend any face to face classes. However much of our e-learning activity has been to *supplement* the learning of our standard on-campus students. Technology supported assessment is very well established and we have for several years employed QuestionMark software, and more recently Perception, as a university-wide system for the automated assessment of many of our students. We are just beginning to see the development of blended learning in which on-campus students do some of their learning through e-learning methods that are a *substitute*, rather than a supplement, for face to face activities, and this is a reflection of our increasing confidence in the use of technology as a valid and appropriate contribution to the student learning experience.

We use a variety of technologies to enhance learning. In recent years there has been something of a standardisation on the use of WebCT, a commercial VLE. WebCT is used fairly extensively throughout the University, and in most respects it appears to be “good enough” as a way of setting up a standard learning environment that is relatively easily accessible by teaching staff with little technical background or experience. However part of the mission of the Department of Information Systems and Computer Applications (ISCA) is to understand and develop information systems, including learning systems, and for many of us the commercial VLE is too inflexible, and rather limited in terms of the enhancement of learning that can be achieved. Furthermore, as WebCT is not open source we find it difficult or impossible to adapt the system itself to incorporate interesting new technical developments such as educational uses for blogs or RSS feeds or activities that require the use of a PHP server to make them more interactive. For example it is bad practice to produce multiple copies of a web page that differ in just one small detail. The reason why is that when we want to change something else on the web page it becomes necessary to change all the static, sibling pages as well. It is much better to represent the variable detail as a PHP variable and allow the PHP engine to build the relevant web page dynamically. This kind of efficiency isn't possible in an environment that doesn't support PHP or some equivalent technology.

WebCT can be used as a hub to register students as a learning cohort, and then make links to third party systems, outside the commercial VLE, where the real learning activities take place. Such an approach seems to have few advantages. Registering a new course in WebCT only to immediately jump outside the system seems to introduce a rather unnecessary layer of administration, and inconvenience, that we prefer to avoid.

Our approach may seem elitist as it depends on developers having some technical and media-handling skills. The rather limited, pre-packaged VLE offers the advantage of an “all in one” system that enables staff with little technical experience to set up some technology enhanced learning, and perhaps more importantly the VLE takes care of many of the architectural issues to do with the design of the interaction among elements such as

web pages, email, or chat software. However over the next few years we will begin to see a new generation of teachers who have learned at school how to set up websites, and who naturally take digital photographs and movies and know how to transfer the results to servers. If we suppose there will be some “reverse mentoring” in which new lecturers teach the new techniques to older members of staff we might soon be in a position where the relevant technical skills to develop multimedia websites from a combination of sources are much more common than they are today, and the desire to be guided and constrained by a simple VLE will be considerably diminished.

## 2. An evolving system

Teaching is a complex activity that can be partitioned into three broad areas.

- The development and provision of learning materials and learning activities. (This is what most people think of as “teaching”.)
- The management and administration of learning and assessment activities.
- The assessment of student achievements, and the marking and correction of their work.

Technology has a distinctive role in all three areas, and there is a body of research effort in all three.

The provision of learning materials requires a well-organised website, and this is true whether developing within a VLE or producing independent web pages. The web is the currently dominant paradigm for learning software, and we assume that all learners are familiar with the use of a web browser. The provision of learning *activities* quickly leads into the use of the more interactive features of web programming, and we make extensive use of web forms so that students can report on their efforts in a structured way, typically for the purpose of formative assessment. More recently, to make our learning website more interactive we have added an RSS feed, and this is reported on further below. WebCT achieves the same kind of asynchronous interaction with students through the use of a “drop-box” that is typically used for students to submit assignments for assessment by a tutor. WebCT also offers an asynchronous discussion board, and while such software is easily obtainable we do not use it because discussion with our students takes place in face to face meetings. In our case, working with on-campus students, the use of discussion software seems to serve little purpose.

Teachers spend a surprisingly large amount of time on management and administration, and a significant part of any course is spent in telling students what they have to do, and when it should be done by. Provided that students habitually consult a learning website, much of this administrative management can be consigned to the website and teachers can stop using teaching time for disseminating administrative information. We have found this to be a particularly valuable way of generating extra time to focus on learning.

Finally certain kinds of assessment can be automatically marked by software. While lecturing to large groups of students presents worthwhile economies of scale, assessment is typically performed for each individual student and the time required to assess large groups is proportionate to the size of the group. Thus automated assessment is particularly attractive as a way for a teacher to save significant time. However the automated assessment of the higher-level skills demanded in a University education remains an unsolved problem that continues to attract considerable research activity, particularly in the area of natural language understanding. Our preference has been to try to make a more traditional form of assessment as efficient as possible.

The technology we use has evolved over a number of years. Our development began with the use of a simple website that provided administrative information, a schedule of activities, links to learning materials such as PowerPoint slides, and links to third party web resources. The presentation of the website has developed over the years, and nowadays we use cascading style sheets to format online and printed forms of the web pages, thus avoiding the need to maintain separate print and online versions.

Web forms are used as a way for students to submit interim work for formative assessment by lecturers. The use of the web forms structures the activity for the students and helps the lecturers considerably with the management of students’ work. Student submissions are automatically filtered for size and documents that are too large are rejected. We also discourage students from submitting work in a form that cannot be read directly using a web browser, so for example Microsoft Word documents are not accepted by the system, but pdf and html documents are accepted. All the student work is routed to a standard directory making it efficient for a lecturer to use a web browser to work rapidly through a set of student submissions. In this way lecturers are able to save a little time by not having to handle paper, or search for mislaid work, or use multiple applications to view the work.

It is also efficient for us to capitalise on pre-existing skills and concepts among our students. They bring to our course a well-developed conceptual understanding of web forms and how they work. Consequently it is natural for them to complete a form to identify their coursework group, and complete subsequent forms to report progress. What is interesting is that students are familiar with the idea of compulsory fields, and so seem less argumentative than students in manually managed groups about having to have exactly four students in a group for example. They also expect instant results following submission of a form, and so are

often puzzled because our forms are manually moderated before we accept their proposal for a group. (We do this to avoid students including fictitious names in the group. There is a better way, which will be in a future upgrade to our system.)

### **3. Enhancements**

Retaining full control over our website leaves us free to enhance the set of learning tools we use, giving us the opportunity to explore promising technologies

#### **3.1 Voice**

Audio-clips, captured from various sources such as interviews or lecture presentations, can be played by clicking a controller in the web page. Audio may also be played automatically when a page is opened. Various software products can be used to produce the audio and embed in the web page. We use mp3 SoundStream which is an excellent low cost system making audio handling easy and effective.

#### **3.2 RSS**

During 2004 -05 we enhanced our learning website by including an RSS feed. One of the problems of web technology in general is that it is an example of *pull* technology. That is to say to read a web page we have to actively choose to bring it up on our web browser. There are billions of web pages on the internet, but we only see the ones we choose to select. If a web page changes we have no way of knowing about the change unless somebody tells us, and this is the key purpose of RSS.

Compare the web with email. If we assume that when you start your computer you also start your email client, then new messages just appear in your mail client without you having to ask for them. The mail server *pushes* the messages at you, and so email is an example of *push* technology.

RSS stands for "Really Simple Syndication", or alternatively "Rich Site Summary", or a third alternative is "RDF site summary". The point is that RSS can turn the pull technology of the web into a push technology. The learners who choose to subscribe to the RSS feed for our web pages receive messages, posted by a lecturer, giving the latest news about the course.

Of course receiving an RSS feed presupposes that the recipients are tuned in to the feed channel. There are three ways they might do this.

An easy way if the learner is using the firefox browser is to simply click on the RSS icon in the bottom right hand corner of the web browser. This will add what is called a "live bookmark" to the browser's list of bookmarks, and users get the latest news whenever they mouse over the bookmark.

For those users who have a yahoo account, a second method is to include the RSS feed as part of their "my yahoo" page. Yahoo currently offer "RSS headlines" as a service for their portal. Thus whenever a new message is posted about our website the user will see the headline in their "my yahoo" page. Clicking on the headline brings up the body of the message.

Thirdly users might download and install a dedicated RSS aggregator such as Sharp Reader. RSS-aware news aggregators came out of the weblogging community, and lots of blogs make their content available as an RSS feed. A news aggregator automatically checks the RSS feeds you have subscribed to, and displays any new items from each of them.

Sharp Reader is a news aggregator for Windows PC users that gives a nice interface allowing subscribers to see the headlines of the feeds they are subscribed to, and by clicking on these seeing the full message, or linking to the website. Starting the reader becomes as natural as starting email and the dedicated RSS reader offers true push technology as headlines pop up with the latest news as soon as any feed is updated.

Our unit Human Computer Interaction Design is a conventionally delivered unit, with lectures and practicals. The website for the unit provides access to online lecture notes, tutorial and practical exercises, course administration information, and links to other web resources. Since 2000 the coursework assessment has been integrated into an extended, project based learning activity that spans the duration of the unit. This activity involves web based monitoring of project stages, online submission of formative work, and online feedback, and is supported by simple web based data processing tools. As a result the unit website is more than a list of static resources, but is also a dynamic and changing tool to assist students manage their learning as the unit progresses. (Crellin, 2003, Crellin and Rosbottom, 2004)

We have usually 'pushed' students towards the relevant parts of the site in lectures, and practicals, by 'reminding' them about impending deadlines, and the web resources they may need to use in support those activities.

We have used a variety of approaches to manage the unit website, and have collected detailed information on individual and group use of resources over several years. A typical daily total count of student web site access shows a gradual decline as the unit runs. We often refer to this as the "declining interest curve", although it probably represents the way students initially explore web resources, and then later access the parts they remember as being interesting or relevant in the current part of the unit.

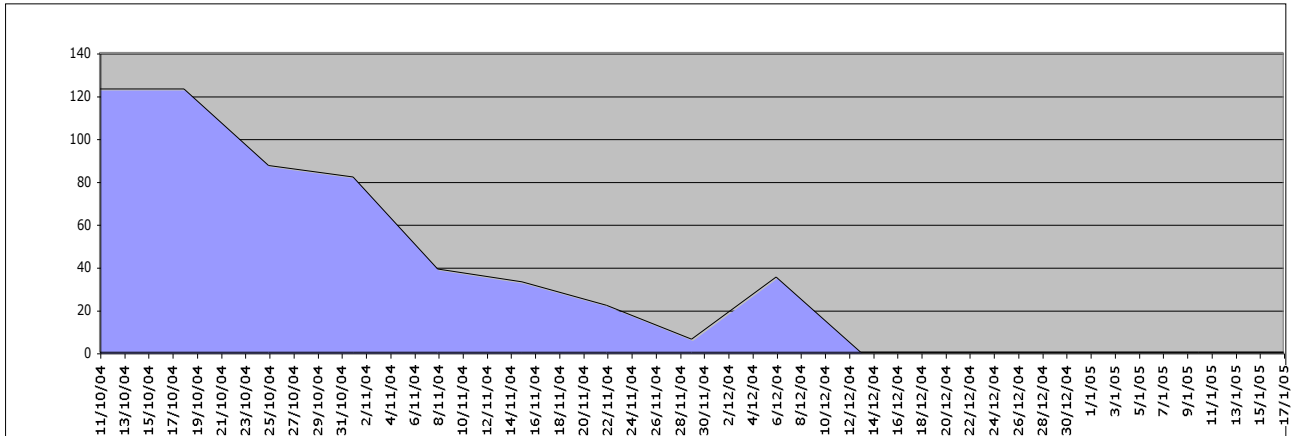


Figure 1: "Decline of interest"

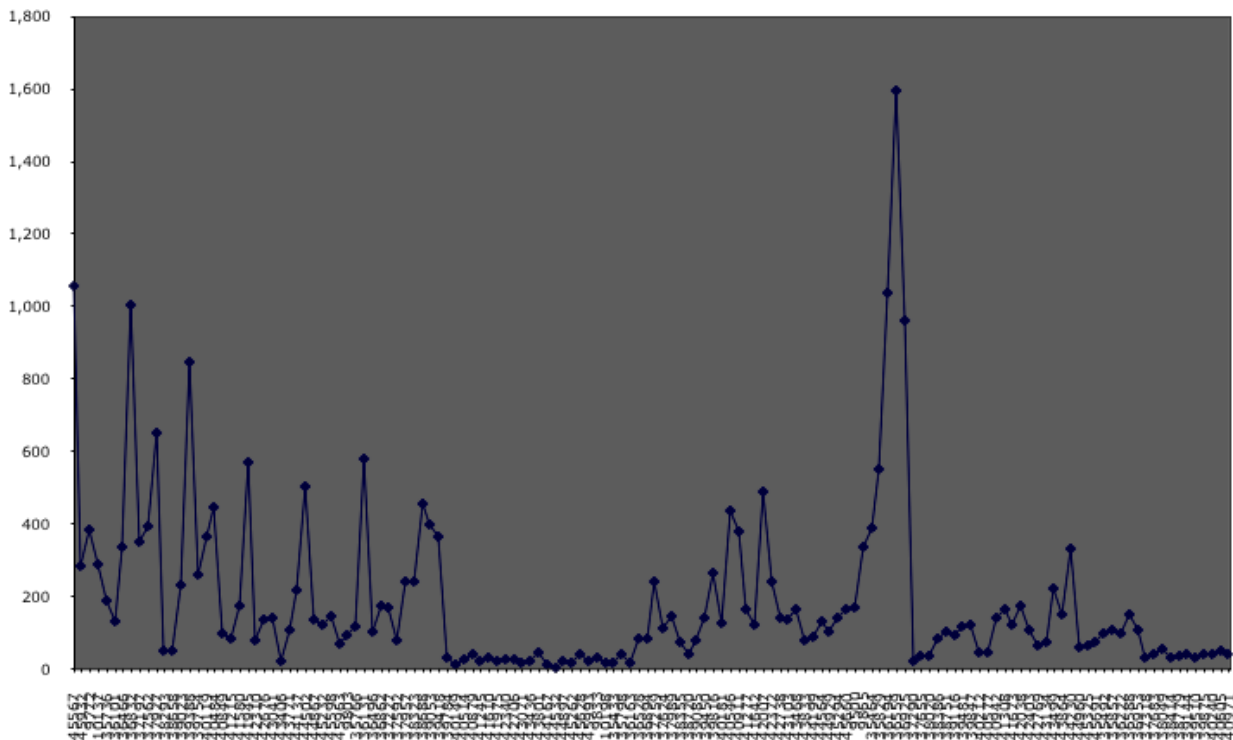


Figure 2: Day by day access.

The inclusion of push technology is intended to help us focus students' attention on the parts of the website (both dynamic and static) that are relevant in each coming session. This can in part be seen as a 'task allocation' problem. By using RSS we assist the students to find relevant resources without relying as much on their internalised mental models of the website structure.

Currently RSS is provided in the unit via FireFox compatible 'add RSS bookmark' code added to the unit website, and via a web page that acts as a unit RSS aggregator. Hence users of modern browsers, and users of older technology such as Internet Explorer can both access the RSS support within the unit.

Evaluation of the impact of RSS looks takes two forms. Qualitative data from survey and questionnaire, and quantitative data from monitoring user activity in the website. Survey and questionnaire data collection is currently underway. Changes in the proportion of usage of different parts of the web site in different stages of unit delivery may indicate the adoption of RSS signposts. We can see some difference in the "decline of interest" curve, in that if anything the post exploration dip is deeper than in previous sessions. This may be due to extra reliance on the RSS tool to highlight interesting and relevant areas of the website. However qualitative data is needed about the reasons for observed behaviour.

Other indicators (such as increased use of RSS enabled browsers) are also possible indicators of RSS use. Approximately 50% of students have used FireFox during this presentation. This contrasts with 16% students using FireFox in the semester one presentation of the unit (comparison of figures of usage at week 5).

### 3.3 Accessibility

We take accessibility seriously and we aim to conform to emerging standards. Research has shown that attending to quite a small number of accessibility issues alleviates the large majority of accessibility problems (Petrie, 2004). Our web site works in any browser that supports CSS and Javascript. Some of our web pages employ Flash for moving images and sound, and hence a Flash plugin is a desirable extra feature. The latter may present problems for the deaf, but our on-going policy is to provide a text transcript for voice clips.

### 3.4 CSS

Using cascading style sheets based on Eric Meyer's excellent s-5 software we are able to offer slide presentations in 100% web format, and this has some advantages over the more common system of including links to PowerPoint files. While PowerPoint is *fairly* universal (at least on Microsoft Windows computers), web pages are even more likely to be accessible on any computer that is connected to the internet on any operating system. Moreover web pages are much, much smaller than PowerPoint files. A 40 Mb PowerPoint presentation involving a mixture of text and graphics becomes only a few kilobytes in size when rendered as a set of web pages. This can be important when slides are offered through a website, as download times are reduced considerably. Add to this lightweight elegance all the power of web processing and a simple presentation can become seamlessly integrated into a powerful learning system.

Compare this 100% web approach with the situation where PowerPoint slides are provided as links in a web page that has to be downloaded and run on a local computer, using a local edition of PowerPoint that is hopefully compatible with the PowerPoint used to create the slides. The diversion of downloading and running the slides in another system is distracting and might have a minor negative impact on student learning.

While PowerPoint presentations *can* be saved as html, anybody with any professional pride would be reluctant to use such poor quality, inelegant, overweight, and hard to maintain web pages.

We also use CSS to provide a print format of the slides. All colour is removed and any words that are spoken in the online presentation of the file appear as printed text in the print version. This is a good example of how web technology can present the same material in appropriate ways for different media. Again the technology is relatively simple using different cascading style sheets for online and printed forms of the *same* file. This use of CSS greatly enhances the future maintenance of information, because there is no need to maintain online and printed forms as separate versions. It really is the same file that is presented in a colourful online form with a voice explanation, and is printed in monochrome with a transcript of the voice. Part of our difficulty in working with WebCT is that within the WebCT environment this kind of control is no longer available to us.

## 4. Dynamic development versus static presentation

Presenting learning materials on day one of a course as a "course handbook", or as a complete website, tends to reinforce the *delivery model* of learning. The well known definition of a lecture as *the transfer of information from the notes of the lecturer to the pages of the student, without ever engaging the brain of either* is a more acerbic description of the delivery model of learning. Course websites make possible a more up to date version of the above definition in which *learning is the transfer of information from the server of the lecturer to the client of the student, without ever impinging on the senses of either*. Daniel Chandler explores this model very well, exposing its strengths and weaknesses. (Chandler, 1994)

Rather than presenting a course as an unchanging static website, would it be better to present it to students as a developing process in which a live website grows from week to week? The intent of such a strategy is to maintain interest and keep the students engaged with the learning process. RSS can be used to post notices, to which students subscribe, keeping them informed of new developments on the website as time goes by.

We are opposed to the concept of providing a course as a fixed entity that can be neatly packaged, tied up with pink ribbon and presented to the students at the start of a course. Such an approach pretends to be professional by virtue of the slick glossiness of the course materials, but fails to recognise that learning is an inherently personal and difficult process. (If learning was as easy as preparing the perfect set of notes governments would not spend so much money on their educational infrastructure.) Learning has to be tailored to the needs of the individual students, and the model of *conversation* is much closer to the nature of learning than the model of delivering content. (Pask, 1975; Laurillard, 1993)

As W.B Yeats put it: *Education is not the filling of a pail, but the lighting of a fire*. Yeats is referring to the importance of motivation. If students can be motivated to take a deep interest in a subject they are able to overcome the difficulties of learning. We believe a course website that develops in parallel with the increasing understanding of the learners is inherently more interesting and motivating than the static website that never changes. Our coursework model employs problem-based learning, and is managed through the website as described above. Research suggests that this approach is more engaging and motivating (Savin-Baden, 2000)

We want to be able to modify our slides on the fly during lectures and store the updated slides on the website. We want to capture artefacts created in lectures such as mindmaps, or even just questions and answers, and copy these to our living website as a record of our activity. We occasionally have guest lecturers; their contribution is not usually available in advance, but we want it on our website. For these reasons and more we want students to use our website as a developing resource that is responding to their learning needs. Of course the dynamic environment we are describing is in great danger of getting out of control so that, if we rely solely on pull technology, maybe only the member of staff doing the updates knows the latest state of play. The news stream via RSS can help keep everybody aware of developments by publicising and recording changes in the website. This is especially important when, as in our case, there are two or more members of staff sharing a common website.

RSS news is essentially asynchronous so students who don't check the feed every day can still catch up on all the news since they last looked.

While it is tempting to teach a course by building the course website *ab initio* as the course proceeds, this may not be the best approach for two reasons. Firstly the highly practical consideration that lecturing staff are extremely busy and may be unable to keep a course website up to date in a timely manner. More importantly it may, despite everything said above, be preferable to prepare a (fairly) complete course website in advance. Students who like to read in advance and explore the whole course, or what comes next, benefit by having a more complete resource. Building a website week by week presumes that there is a "best way" of doing the development, but such a supposition fails to take account of the variability in human learning where what may be "best" for one is less than optimal for another. The key thing for students to understand is that the "complete" course website presented on day one is subject to modification in the light of how the course develops. The dynamic vivacity we are seeking can be approximated very well by updating the website in the light of current course activities and interests, and by using RSS to send a message to subscribers in order to keep them up to date on any changes. This last model where a relatively static website is modified as a course proceeds, and news of the modifications is broadcast via an RSS feed, is the model we propose to further develop in our future teaching.

## 5. Emergent properties

"The whole is more than the sum of the parts" is a well known epithet in English. In relation to our work the point is that the richness of our learning website is an emergent property, that comes out of the way we have combined simpler components. An analogy is the way that "area" is an emergent property of a triangle made from three lines. The lines are simple entities that do not have area, but their combination produces a more complex entity having additional, emergent properties.

There is nothing remarkable about the individual features we use in our website, and while they all have some value for learning they are each certainly incomplete, but taken together as a whole they begin to form a useful learning environment. The issue here is not just completeness - if this were the case we would simply be combining learning elements like a jigsaw puzzle until we achieved something that was complete. In such a case the whole really would be the sum of the parts. However what we are looking for are learning opportunities that derive from the combination of parts, superimposing learning value that exceeds the value intrinsic in the individual elements.

Flocking behaviour in birds is often presented as an example of an emergent property. Individual birds behave according to very simple rules, for example Dimock and Selig use the following rules to generate complex flocking behaviour of simulated birds: cohesion (steer to move toward the average position of local flockmates), collision avoidance (steer to avoid crowding local flockmates), alignment (steer towards the average heading of local flockmates) and drag reduction (save energy). Out of these simple rules comes the complex behaviour we call flocking in which the behaviour of the flock appears much more intelligent and complex than that of any individual within the flock. None of the birds is a general in overall command of the flock, the flocking behaviour is an emergent property. Can we compare a learning website composed of small relatively independent systems with one that is governed by a preconceived masterplan and expect to draw out analogous emergent properties in the system developed "bottom-up" that compares favourably with the "top-down" driven system of the VLE? In this case the website is the medium in which the action happens, rather like the air in the case of the birds.

It is claimed that Admiral Nelson's victory at Trafalgar was attributable in part to his instructions to the captains of his ships to sail into the French fleet and use their skills of seamanship to cause mayhem. While the French admiral attempted to manage the battle through a more text-book "top down" approach involving a master plan that was transmitted to the ships through a chain of command. The English victory can be interpreted as an emergent property of the English ships individually seeking to damage the French fleet using some simple rules, and therefore operating more efficiently than the French ships who had to wait for orders from above. Out of the combination of the destruction created by the English ships there emerged a destructive force that was greater than the sum of the individual efforts, leading to the loss of the French fleet.

Learning itself is a form of emergent behaviour. There are no guarantees in the world of education. We can only aim to increase the likelihood that the behaviour of a student may change. A child might learn multiplication tables by rote while at school, and practice various mental arithmetic exercises, but this does not guarantee the adult who develops will be able to calculate the change required when paying for some goods on a shopping trip. The ability to calculate change in the shopping context is a rather simple emergent behaviour. If it were possible to package a set of processes and a collection of information that would guarantee learning then such a package would be worth a fortune. Governments spend huge sums of money on an educational infrastructure with the aim of increasing the probability that citizens will learn something useful. In higher education one of the key aims is to turn students into reflective practitioners. This might be in any field from surgery to philosophy. However reflective practice is a form of emergent behaviour. We can only offer some kind of initiation into ways of thinking that involve relevant concepts, and exercises that practice relevant skills (Peters, 1964). But these concepts and skills are generally at the level of birds knowing they need to stick together and avoid crashing into a neighbour. Reflective practice emerges out of the initiation process, but as with education in general, there are no guarantees of success.

In order to test the claim that there are some genuine emergent properties in our learning website we study the behaviour of the users as described in 3, above. The learners do seem to find the website useful, and continue making use of it in ways that change throughout the course. Everything we do can be achieved through a VLE such as WebCT by utilising third party resources, outside the VLE. There comes a point however when so many third party resources are being used the VLE itself becomes of minor significance, and we may be in this situation.

We often talk about the importance of “learning to learn” as a key life-skill. Once again this is not something that we can guarantee. Flexibility, adaptability, and knowing what to do in new situations are skills that employers value in University graduates, and these skills are emergent properties that derive from the ability to learn rapidly and successfully. In higher education we encourage the latter and hope the former will emerge.

Can we compare a learning website composed of small relatively independent systems with one that is governed by a preconceived masterplan and expect to draw out analogous emergent properties in the system developed “bottom-up” that compare favourably with the “top-down” driven system of the VLE? In this case the website is the medium in which the action happens, rather like the air in the case of the birds. Our strategy of maintaining a loose, easily modified learning platform enables us to take advantage of interesting new approaches and technologies, and to combine these in ways designed to enhance the possibility of students learning something useful is based on the idea that such emergent behaviour is more likely the more the learning medium can be tuned to the precise needs of the students. We suspect that the VLE that presents teachers with a more rigid, highly structured environment may be less efficient as a way of promoting learning. Such an approach would be fine if learning was a deterministic process, but in practice we know this is not the case. On the negative side our more individual approach requires students to spend time on what is in effect an administrative matter of learning the structure of our website. We try to use good HCI practices to make the operation of the website as transparent, and as easily navigable as possible, but there is nevertheless an undesirable administrative overhead.

We are not comparing black and white here, but rather two shades of grey that change colour depending on our point of view, and there are real advantages in the standard platform of the VLE compared with our more ad hoc approach. However in our opinion one of the great qualities of good teachers is their adaptability, and that teacher-adaptability is what our system promotes. The VLE constrains teachers more strongly than our loosely configured set of web tools and this, in our opinion, is an inherently inferior approach that discourages the kind of emergent behaviour we are trying to encourage.

## **6. Conclusions**

The interesting thing about our approach is that while any individual technology we use is relatively simple to set up and use, the combination of technologies gives what appears to be a complex learning space that is robust, accessible, very flexible, dynamic and relatively easy to maintain.

We have a preference for developing learning resources by combining relevant technologies because we are able to adapt our learning system to new technologies much quicker than the providers of a commercial VLE. Also we believe that we are better able to match the precise learning needs of our students compared with using a commercial VLE.

The shared effort embodied in a genuine open source VLE may prove to be a better model for Universities in general because open source software is inherently more adaptable than commercial equivalents. It remains to be seen whether open source VLEs such as moodle (Moodle 2005) will supersede the proprietary systems such as WebCT or BlackBoard. Our guess is that the customisation made possible by open source software will prove to be a significant advantage in the world of education where teachers need to respond quite sensitively to the needs of their students. Our own situation, working in an Information Systems department

makes it easier for us to adopt the kind of flexible and adaptable learning space that good quality education demands.

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