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Designing for Tacit Learning: an investigation of design strategies for multimedia supported learning in the crafts

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Abstract

There is an increasing interest and activity in the design of interactive multimedia to support learning in all fields of education and training. However, most of the theory to support such developments is concerned with learning explicit knowledge and there is little guidance available to designers of material for learning in areas with an element of tacit knowledge such as craft skills. This paper describes the foundation work for a long-term project concerned with learning in traditional rural crafts but with the intention to provide a methodological framework for the design of multimedia-based learning in all areas of craft knowledge.

A review of established theory of learning and the use of multimedia for learning in areas of explicit knowledge indicates some important basic principles, for example the need to understand the interaction between the teacher and learner in the context of the subject being taught and the need for clear narrative structures to avoid students becoming "lost" in the multiple pathways of interactive media.

Observational studies of learning using educational video in a craft context and a study of an experienced craftsman/teacher teaching a group of learners, complemented by study of learning in related contexts, have allowed problems and issues to be identified and design strategies to be developed. While these are provisional they provide an overview of the design problems and have been used to plan a programme of experimental design and

evaluation to test and develop principles of effective multimedia design for craft learning.

Background to the project

There is an increasing interest and activity in the design of interactive multimedia to support learning in all fields of education and training. However, most of the theory to support such developments is concerned with learning explicit knowledge and there is little guidance available to designers of material for learning in areas with an element of tacit knowledge such as craft skills. This paper describes the foundation work for a long-term project concerned with learning in traditional rural crafts but with the intention to provide a methodological framework for the design of multimedia-based learning in all areas of craft knowledge.

Context for the research

Traditional crafts have played an important role in shaping British cultural identity and although the products, tools and film/photographs of traditional craftsmen[1] are being preserved in museums, the skills themselves are gradually being lost. In England, important buildings are preserved through legislation that protects them from change to keep them as "powerful reminders to us of the work and way of life of earlier generations" (English Heritage 2002) and wildlife habitats are designated areas Sites of Special Scientific Interest to preserve this "increasingly precious part of our natural heritage" (English Nature 2002). Whilst the original purpose of many rural skills may no longer seem significant, they have played a vital role in shaping the landscape, buildings and interiors that we seek to preserve. As the Heritage Lottery Fund (2002) recently commented, "the United Kingdom's heritage is, in part, the product of generations of skilled labour" and without these craftspeople many ancient and historic sights are becoming irreparably damaged or having their unique character spoilt by modern repairs.

In the past rural crafts were taught through apprenticeship, either formally or informally, handed down through the generations by working alongside an experienced craftsman. There seems little likelihood of a return to such a system, but there are an increasing number of "independent learners", whose learning is self-directed and who are motivated by internal incentives and curiosity (Durbin 2002). They may have some opportunities to study for short periods with experienced craftsmen but this is not sufficient for them to develop a useful level of skill and they need for materials for independent learning. The aim of this project is to identify and evaluate a framework that can be used to record craft skills in multimedia form, not just as an archive, but also as a learning resource with the desire that they shall inspire people to learn and develop traditional crafts. We are concerned therefore with how this kind of learning takes place and can be supported by multimedia.

In undertaking this we are also aware that the principles developed in the research may have applications in any area of work where craft skills are

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[1] Some readers may consider the term *craftsman* to be politically incorrect and we understand their concerns. We use it here because it continues to be used in context of rural crafts to describe a skilled practitioner of a craft, irrespective of their sex.

employed and this is relevant to a great number of trades and professions, for example our review includes practices in the training of surgeons.
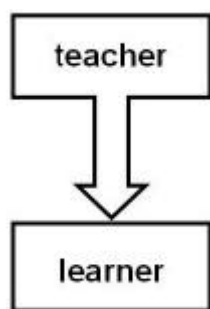
Learning theories

James Atherton (2002) suggests that "teaching" as an activity cannot exist in isolation, but must be considered in terms of the interaction between the teacher and learner in the context of the subject being taught. The situation is a dynamic one according to variables such as:

the teacher's level of skill and preferred teaching style

the learner's motivation, level of skill and preferred style of learning

the subject; at some stages it could be linear, with the basics needing to be learned in a set order, at others it could allow greater freedom

The following diagrams describing the different learning/teaching theories are based on Atherton's "Sculpt" models (Atherton 1999) to represent the basic relationship between the teacher and learner, with their vertical position suggesting their relative dominance in the given context.


Fig.1 Socratic Dialogue

Socrates' (469-399 BC) believed that learning was understanding the "true" nature of things and everyone had the knowledge within them, it just needed drawing out. He gradually guided his students to a level of understanding through careful questioning, though they were required to answer little more than "yes" or "no" to his questions (Laurillard 1996).

In this classic form of teaching, there is a vertical relationship between the teacher and learner, where the teacher is in a dominant position and bestows knowledge upon the learner. The teacher has control over the subject and the power to select from the material and pass on what he sees fit.

Cook (2001) suggests this is only really suitable for rote learning set tasks. In the context of learning abstract knowledge this may be the case, but for practical skills it has proved successful for many centuries as the way a traditional master craftsman trained an apprentice.
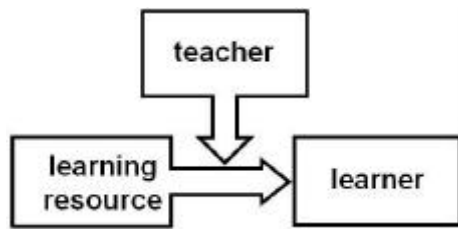
Fig.2 Adaptive dialogue

In the adaptive dialogue situation there is a less vertical relationship between teacher and learner. The teacher is still dominant, though their teaching is now aided by a learning resource, which could be a book, a video, an educational TV programme or multimedia disc. The teacher still guides the learning, but now as a mediator between the learner and the learning resource, with the critical point being that the teacher *actively engages* with the learning resource to assist the student's understanding.
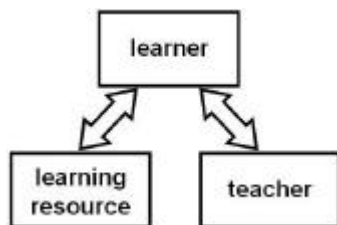
Fig.3 Constructivist learning

In the constructivist learning theory, knowledge cannot exist independently of the knower, but must be constructed through their own understanding of the situation. Therefore the learner should not try to passively receive and store skills and knowledge from teachers or learning resources, but actively construct them (Hein 1991).

The learner is the dominant factor and they use learning resources to construct their knowledge. When required, the teacher's role is to provide guidance in the form of "scaffolding"; supporting the learner by providing the tools with which they can construct their knowledge, but not actually engaging with the learning resource (Yazici et al 2001).

The way in which the learner constructs knowledge depends on the complexity of the task, with a range from pure discovery for simple tasks, to an increasing need for guided discovery for increasingly complex tasks.

Multimedia as a learning resource

The MENO project (Multimedia, Education and Narrative Organisation) based at Open University has used observational studies of school, college and university students using a variety of multimedia CDs and the sessions have been videotaped to allow detailed analysis of the users behaviour afterwards. In addition, the students have been interviewed about what they found out and their teacher asked to judge how well they have done after each session in order to triangulate the data (Laurillard 1996).

Results of their initial studies using commercially-available educational CDs concluded that, if left unsupervised, students "will under-specify the problem, be distracted by irrelevancies, be unsure how to evaluate the information they

find, over-generalise from instances, remain unaware of incompleteness, fail to recognise inconsistencies ... there is every opportunity to fail to meet the objective." (Laurillard 1996)
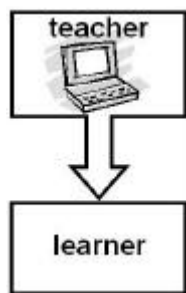
Fig.4 Multimedia as Socratic Dialogue

The multimedia potentially provides students with a rich Socrates-like resource, but it is *they* who have to provide the questions to elicit the knowledge and they scarcely know enough to frame the questions. So, by simply replacing the teacher with a learning resource, the dialogue is destroyed and effective learning not achieved.

Narrative structure

Educational media, such as lectures, books and educational TV all tend to follow a narrative form. The storyline provides a linear structure that takes the learner sequentially through the material so they can understand its full meaning.

This is a device that has been used for centuries. In *The Poetics* (350 BC), Aristotle states that narrative events "must be so arranged that if any one of them is differently placed or taken away the effect of wholeness will be seriously disrupted. For if the presence or absence of something makes no apparent difference, it is no real part of the whole" (Plowman 1997).

Multimedia resources are essentially non-linear in form. The learner chooses their own path through the material, leading to the possibility of many different story lines. Whilst this could be seen as beneficial; the learner has the choice of what they do and in what order; it cannot be guaranteed that they will follow the necessary cohesive, sequential path through the media to achieve their learning aim.

Cognitive overload

There is also evidence to suggest that learners can spend so much time working out how to navigate the resource that they forget about the task in hand.

Using classroom observations of students using encyclopaedia-style CDs, Plowman (1997) found that the decision-making process involved in searching and navigating the resource took up so much mental activity that there was little left for understanding what was found and this "cognitive overload" was observed with more experienced users as well as novices.
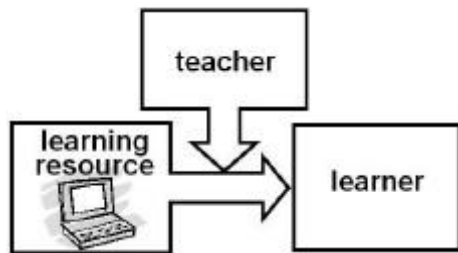
Fig.5 An interim solution for multimedia

Laurillard (1996) suggests that these multimedia are still very much of value, but should be used under the guidance of a teacher rather than in isolation. With the re-introduction of a teacher, the context becomes an adaptive dialogue with the teacher mediating between the learner and the learning resource when necessary.

Affordances for learning

Laurillard et al (1998) illustrate the concept of an affordance thus:

> *a door with a handle affords pulling*

> *a door with a flat plate affords pushing*

Following their observational studies of commercially available CDs and an evaluation of other educational resources, the MENO project made their own multimedia resource for an Open University course learning about the classic writings of Homer. The students were given an overall task to investigate using the text and other resources on the disc, but the narrative was made explicit through a series of sub-goals from which the user could choose. A "notepad" facility was introduced to encourage the user to express their findings that then gave them access to a model answer for comparison.

After putting this through the same evaluation process they concluded that these design elements allowed the students to learn more effectively (Laurillard *et al* 1998). They were affordances for learning.
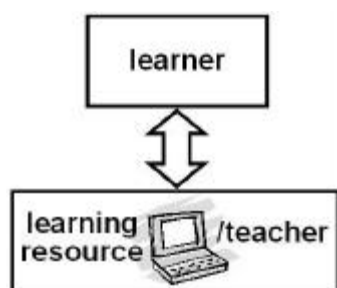
Fig.6 Meno model for multimedia

In terms of learning theory, the learners are now constructing their knowledge using the CD that combines the roles of learning resource and teacher. The key elements identified by the MENO team to enable this to happen were:

Navigation - to make the narrative explicit

Goals & sub-goals - to provide motivation

Interaction - so the learner expresses their knowledge

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Model answers - so the learner refines their knowledge

This has given us some useful theory for designing multimedia materials but the MENO studies are concerned with learning explicit knowledge and we did not consider them a reliable guide to designing learning resources for craft skills in which tacit knowledge is very significant.

Surgical skills training

Traditionally, surgical training has also been taught through apprenticeship, learners watching and assisting, and taking an increasingly active role as experience increases. As minimally invasive techniques are becoming more common, computer-based training that simulates the processes are also being developed (Tendick *et al* 2000). Much of the research is into developing increasingly sophisticated virtual reality training models which is not so relevant to our work, but the basic analysis of surgical skill and the underlying structure of the computer-based training are both relevant.

Early experimental training resources which attempted to simulate entire operations were cumbersome and deemed to be less effective that watching and participating in a live operation. Instead, it was realised that in every operation there were a series of key actions which, if performed incorrectly could lead to complications. More effective training resources were then developed, concentrating on these critical steps and common errors for each procedure which, along with the basic strategies and key skills required to perform the task, could be defined by a skilled surgeon. Attention was drawn to the fact that a skilled surgeon also uses perceptual-motor and spatial skills that cannot easily be expressed verbally or reproduced by a training resource. (Tendick *et al* 2000).

Observation 1 - Craft learning through educational video

To gain some insight into the interaction between the learner and learning resource in a craft context, we carried out an experiment in which a learner used an educational video to construct such a skill. The learning resource used was the video *Turning Wood with Richard Raffan* and a learner (Robin) chosen who had a good craft skills and practical knowledge, but no prior experience of wood turning. A TV and video were set up next to the lathe to allow the learner easy access to both and the whole session was recorded on video to allow full analysis afterwards.

To gain a general overview of the task in hand, Robin spent half an hour watching the portion of the video to be used straight through at home, and then prepared several pieces of green sycamore to turn. he spent a further 1¾ hours in the workshop, excluding breaks, of which 52 minutes was spent at the lathe, 38 minutes watching the video and 15 minutes on other activities such as sharpening tools and adjusting the tool rest.

With straightforward tasks, Robin would watch the video briefly (less than a minute), and then spend longer periods (4-5 minutes) on the lathe. With more difficult procedures, he would swap rapidly from the lathe to the video and back again (1-2 minutes) on each.

Having the video beside the lathe enabled easy comparison between what he was doing and Raffan's technique. Frequently he would mirror what was

happening on the video with the lathe switched off to get the stance and grip correct or freeze the video at a vital point so he could look at it whilst turning.

Unfortunately Robin often watched the video with the lathe on and wearing a facemask, so it was impossible to hear what Raffan was saying. At one stage Robin commented (when switching the lathe off) that he wished to listen to what was being said indicating that he was basing his learning largely on visual processes, whereas Raffan later pointed out that hearing the sound of the cutting process is very important" .

The differences between the equipment used by Raffan and that available to Robin caused frequent problems. Firstly Raffan's turning tools were different, leaving him uncertain if this was a cause of his initial difficulties, or if it was just down to technique. The tool rest on the lathe was different to Raffan's, causing frequent problems and leading Robin to having to adapt Raffan's techniques. This element will have to be taken into consideration when making recordings.

Robin's frustration with navigating the video was clearly evident. He could be seen tapping his foot in impatience as he waited for it to rewind, and sometimes overshot so then had to fast forward to where he wanted. This left some problems unresolved, such as the buzzing noise that the tool sometimes made against the wood, because he did not wish to spend the time looking for the answer.

Student's comments

Robin found there were small parts of the video he wished to watch over and over again as he practiced vital moves over and over again. He would have liked to set those portions of video on a continuous loop so he could look up from his turning at any point to observe what Raffan was doing. He generally found use of the video to be slow, clumsy and frustrating.

He felt that, with the video, he was learning skills he just could not get from a book, but the learning process was much slower than with a teacher. When faced with minor problems, such as getting a clean cut in the bottom of a groove, he would have liked somebody to tell him if it was technique, that his tool needed sharpening, or just the grain in the wood. Effectively he was left at the "pure discovery" end of the spectrum when he would have liked some guidance, although it could be argued that constructing his own knowledge at this stage could be beneficial for problem solving at a later date.

Teacher's comments

The original intention had been for Austin Neves, whose workshop was used, to act as an additional observer in the process. He teaches adult education classes in woodworking so it was hoped he would have some useful input, but it became apparent very soon that this was not going to work out.

He clearly lacked sufficient confidence in the teaching resource and was worried about Robin doing something dangerous. He unease caused an initial false start; using a piece of dry beech because he considered the green wood Robin had prepared to be in danger of flying off the lathe as it was not very square. We were quite relieved when, just before we started, he announced he had another appointment and could not stay to observe the session.

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At a later date I watched the video with a colleague (Tom Fisher), who also has experience of wood turning and teaching. He felt that overall Robin had made good progress learning techniques, but that at this basic level what was lacking was confidence building. Being completely without a mentor figure, the student has to look to the learning resource to solve problems and provide feedback, which is where the video fails. As navigation is slow, even if it had the equivalent of "Frequently Asked Questions" it would not be easy to access them to solve problems.

Maker's comments

Email correspondence with Richard Raffan revealed that his initial intention had been to make an audiotape, but the publishers decided on video instead. He considers sound to be a vitally important part of the learning process and an audiotape would have made a portable resource that could have easily been taken to the workshop. The video was first produced in 1985 and has since sold 50,000 copies, far in excess of original expectations.

He also commented that there has been talk of converting the video to CD, but the publishers are worried about too many pirate copies being made.

Conclusions from the wood turning exercise

Looking at the results in the context of the key elements identified by MENO:

Navigation - making the narrative explicit

As video is linear in structure, the narrative is pre-determined, but problems arose when the learner wished to review sections of the resource or find solutions to problems. The latter were left unanswered due to the lack of effective navigation.

Goals & sub-goals - providing motivation

The material on this particular video is well structured, taking the learner through exercises with each tool then providing practical projects to apply the knowledge.

Interaction - expression of knowledge

In the context of a practical skill, the learner interacts with the task in hand rather than the learning resource to express their knowledge. Having the video next to the lathe was important to enable the learner to consult frequently when addressing a difficult task. A laptop computer with the material on CD would be more portable than video or an on-line internet resource.

Model answers - refining knowledge

This proved to be the key problem area. The learner had a "model answer" in terms of being able to see what Raffan had produced, but it was not what was required to enable him to refine his knowledge.

Observation 2 – Formal learning with experienced craftsmen/teachers

To examine the interaction between learner and teacher in a craft context, Nicola Wood observed short courses taught by two different craftspeople. Again, video-recordings were made for later analysis and one of the students

was interviewed before and after each course to discover, in particular, how it compared with their expectations.

Owen Jones, oak swill basket-maker

Swills were once a common working basket used all over England in agriculture, industry, mills etc and are woven from strips of oak. They were all originally made in the small area of the Lake District where Owen now lives and he learned from one of the last swill makers, who by then was semi-retired.

Owen has run more than 50 three-day courses over the past 12 years. Participants (no more than 8 in each course) go through each process in preparing the materials and each makes a basket to take home. Due to time constraints, they do not do everything in the required order and weave their baskets largely from material Owen has pre-prepared, though they do get the opportunity to prepare material.

At the end of the course he likes everybody to go away with a good basket and a good feel for how it was made, but admits that over 3 days they cannot gain enough skill to make another unaided. He gives an open offer for anybody to come a spend more time working with him if they'd like to improve their skills, but so far nobody has!

The first half of the course was spent preparing the strips of oak that make up the basket and, as the material is highly variable, many subjective decisions had to be taken. Owen split the learners into groups of two or three and gave them plenty of time and wood to experiment and make mistakes with. He encouraged them to make their own decisions through group discussion and, when his opinion was asked, he tried to make clear the thought process he was going through to come to his decision. The time required for "boiling" that materials prevented the learners from working with the material that they had prepared themselves, so they lost an opportunity to learn from their own mistakes.

During the second half of the course each of the learners wove a basket. Owen makes his baskets exactly as they were traditionally made and does not allow his learners to make any variation. The learners also only have time to make one basket, and he wants it to be a good one, so he also does some judicious correcting of mistakes whilst making sure the learner still feels that they made the basket.

Ana Balfour, traditional bread making

Ana owns and runs a traditional watermill which is used to make a range of different flours with emphasis on organic British produce, which is very different to modern commercially-available flour and needs handling in the traditional way to bake successful bread. Ana has run courses for the last 10 years to teach people about traditional flour and how to bake with it.

The course starts with a detailed background talk, covering different wheat varieties, other grains, production methods, aspects of milling, the chemistry that goes on when you make dough etc. Ana then demonstrates the technique whilst the learners watch, encouraging them to also feel, smell and listen where appropriate. Then the learners take it in turn to make bread

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themselves, but this is done as a group activity with Ana encouraging everyone to help the maker make subjective decisions before putting in her opinion. The result is that, although they only make one loaf each, they experience the decision-making for 5 or 6 loaves. Most of the bread is out of the oven in time to be sampled with lunch and the course concludes with a tour of the mill to see it working.

Ana emphasises the need to start bread making as soon as possible after the course whilst it is still fresh in the learners minds and for them to bake little and often whilst they build their skills and learn to adapt their technique to their situation.

Developing theory from the research

Owen Jones used two different teaching styles, reflecting the differences in what he was teaching. For weaving the baskets his style was very much a Socratic dialogue; he was the "master" dictating to his apprentices how the task was to be done.
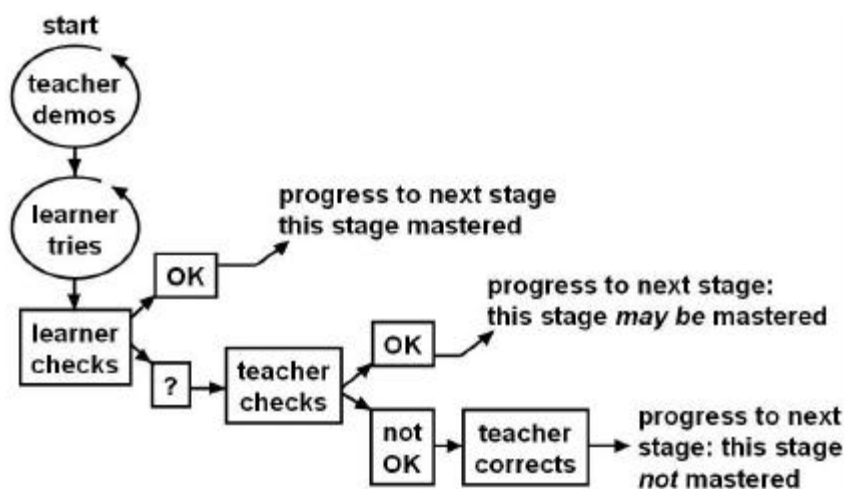
Fig.7 Socratic Dialogue used by Owen Jones

In a traditional apprenticeship situation the learner would go through this process many times until all stages were mastered, though the time constraints of the course meant that the learners only went through the complete process once.

When processing the oak, Owen let the learners make their own decisions and mistakes, simply giving advice when asked as in the constructivist learning theory. This was also the style that Ana adopted throughout the bread making course, allowing learners to construct their own knowledge.
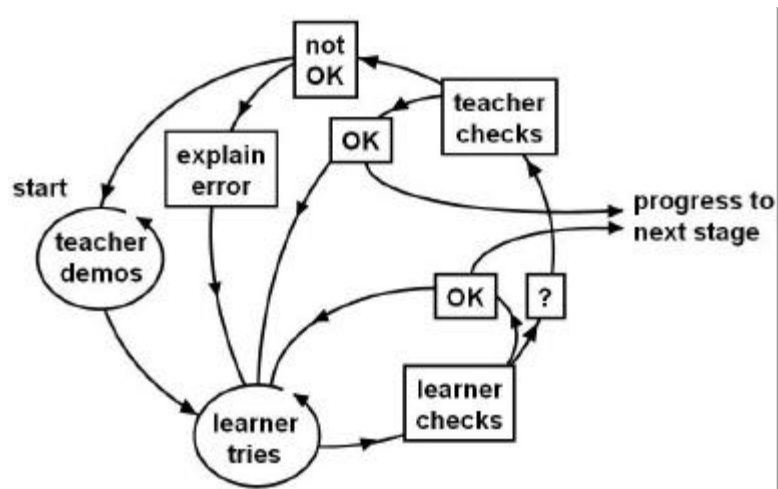
Fig.8 Constructivist Method used by Ana Balfour

This process takes the learner through all three phases of learning; cognitive, associative and autonomous (Fitts & Posner 1967):

COGNITIVE (where the learner acquires an understanding of what is required) is the passive, watching part when key skills and strategies are explained.

ASSOCIATIVE (where the learner determines how to execute the task in hand) is the active, doing part where critical steps and common errors are understood.

AUTONOMOUS (where the task has been mastered and become automated) is the repetitive part where perceptual-motor and spatial skills are learned.

Conclusions – a framework for a multimedia craft learning resource

Fig.8 provides a description of the constructivist learning process which draws together our observations of learning and the theory developed by MENO. The final step in the research has been to translate that into a framework (Fig.9) in which a multimedia resource can help the learner to mediate the process when there is no teacher available.
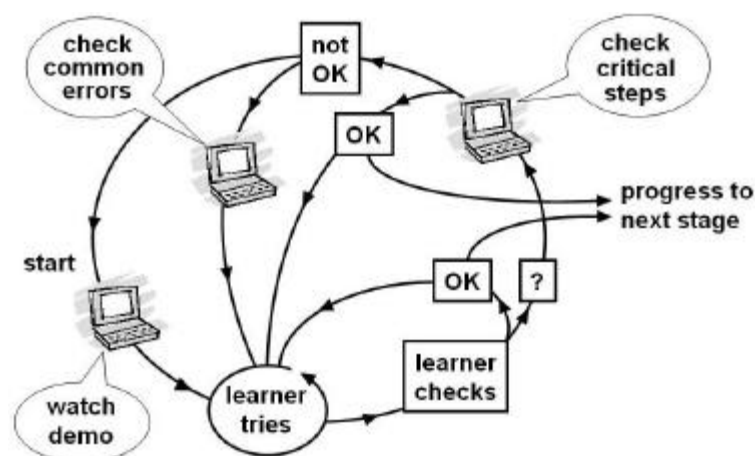
Fig.9 A Constructivist Method Using Multimedia

The learning resource is structured to allow the learner to progress through each phase, at present encouraging them to follow the desired path through the material rather than making it compulsory, but this will be reviewed after initial evaluation.

At the cognitive phase the learner is offered a range of background information to aid understanding of the strategies to be adopted and the opportunity to watch a video of the complete process to gain an overview of the skills to be learned.

At the associative phase the process is shown broken down into critical steps with an explanation as to why each step is performed and a video clip demonstrating how. Common errors are also highlighted at this stage.

The autonomous phase can only be reached by the learner repeating the process many times. This is encouraged through a problem solving section that allows the learner to assess how successfully the process was performed, identify where errors occurred and review the appropriate section in the learning resource before trying again.

Continuing research

The next part of the research is to construct a prototype multimedia resource for craft breadmaking and evaluate/develop it progressively with a variety of learners. This will allow us to propose a more complete and more robust model for multimedia craft learning, as well as explore some of the more detailed design problems involved.

We will use direct observation of learning, aided by video-recording, interviews to review the process and follow-up work to monitor progress of learners who carry on using the resource at home. We are also developing activities that involve learners in reviewing and developing the theory and structure of the resource, for example by adapting the "cardboard computer" methods of Ehn and Kyng (1991) to provide an accessible and easy to manipulate graphical model of the learning process.

To provide some quantitative support for evaluation we will use activity logging software (eg Holmquist & Narayanan, 2002) to track the learners' paths and time use. Finally we will introduce the software to people in a "real-world" context by providing the resource on CDROM to people attending Ana Balfour's courses, as an extension of the course, allowing us to assess it in its intended context.

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Biographies

Nicola Wood is a professional interactive media designer and a researcher at Sheffield Hallam University investigating applications for multimedia in learning. Her early background was in business and she has provided both organisational and creative support to a number of community-based and charitable organisations as well as to mainstream business.

   She developed an active role in the preservation of rural crafts through working in partnership with her husband, who has been a pioneer in rediscovering lost woodworking skills. This has provided the background to her current research, which involves collaboration with museums and craftspeople as well as engagement with questions of multimedia design.

Chris Rust started his career as a marine engineer, going on to work in engineering design and project management before taking early retirement at age 27 to pursue his interest in music and performance. He studied Industrial Design in his 30s and his professional work since then has been concerned with vehicle design and design for people with disabilities, leading to a British Design Award in 1992. In 1990 he joined Sheffield Hallam University where he is now MA Design programme leader. His current research is concerned with investigative design practice and the role of tacit knowledge in design practice and research.

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