The Use of an E-Learning Constructivist Solution in Workplace Learning

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ABSTRACT

We wished to investigate whether an e-learning approach which uses constructivist principles can be successfully applied to train employees in a highly specialised skill thought to require expert individuals and extensive prolonged training. The approach involved the development of an e-learning package which included simulations and interactivity, then experimental testing in a case study workplace environment with the collection of both quantitative and qualitative data to assess the effectiveness of the package. Our study shows that this e-learning strategy improved the skills of the inexperienced operator significantly. We therefore propose that such programmes could be used as a work based training aids and used as a model system for the training of employees in complex skilled tasks in the workplace. This research demonstrates that the e-learning can be applied outside the traditional learning environment to train unskilled employees to undertake complex practical tasks which traditionally would involve prohibitively expensive instruction. This work also

illustrates that simulations and interactivity are a powerful tools in the design of successful e-learning packages in preparing learners for real world practical situations. Finally this study shows that workplace learners can be better served by e-learning environments rather than conventional training as they allow asynchronous learning and private study which are valued by employees who have other demands on their time and are more comfortable receiving tuition privately.

Relevance to Industry

E-learning using constructivist principles, and incorporating simulations and interactivity can be used successfully in the training of highly specialised and skilled tasks required in the modern workplace.

Keywords

e-learning, constructivism, workplace learning, simulations, interactivity.

Introduction

In recent years workplace learning has embraced technology to meet the demands of continuing professional development and general training of employees. Little research however has been undertaken in this field to assess the effectiveness of the methods used and the reception to these styles of teaching by the learners. E-learning package designers often apply similar principles to these packages as to those aimed at students or younger learners with no evidence of their success.

It has been debated at length whether andragogy (andragogy is the term given to the education of the more mature learner (often in the workplace)) and pedagogy differ, Knowles (1980) reached the conclusion that four of the five assumptions applicable to children and students were actually also appropriate to adults. It was apparent to him that the only major difference that distinguished these two sets of learners was that adults have gained a range of experiences, whereas students have a limited amount and therefore, rather than the learning being based on chronological age it should be based upon such experience.

In this study we suggest that since learning in the workplace should be based on experience not only of related topics to the one being instructed but also of the learners knowledge of their own learning style, constructivism rather than behaviourism or cognitivism should be the theories of choice for these learners. Indeed research on how people learn in the workplace demonstrates that what is taking place is often constructivist, situated learning, often through cognitive apprenticeship. The constructivism theory of learning considers learning to be an active process where learners construct concepts based on their own current and past knowledge. Two common themes of constructivism have been identified by Duffy and Cunningham (1996). Firstly, learning is an active process of constructing rather than acquiring knowledge and secondly, instruction is a process of supporting construction rather than communicating knowledge. This leads to the emphasis on the importance of the learner gaining practical experience in an authentic learning situation. Brown, Collins and Duguid (1989) argue that learning and cognition are fundamentally situated and is in part a product of the activity or setting in which it is developed, emphasising that the learning experience is enhanced if the subject matter is as close to being a real world situation as possible i.e. the “Fidelity Principle” (van Merrienboer and Kester 2005). Studies of practitioners in several professions by Farmer, Buckmaster, and LeGrand (1992) reveal that what helped them most in learning to deal with ill-defined, complex, or risky situations is having someone model how to understand and deal with the situations and guide their attempts to do so. Jonassen (1992) calls for e-learning to embrace a constructivist approach to e-learning systems. In e-learning this is often accomplished through the use of interactive games or simulations (for example, Rieber, 1990 and de Jong & van Joolingen, 1998). Therefore simulation and interactivity in e-learning, as we will show, is the method of choice for training of complex tasks in the workplace.

Boud & Feletti, (1991) proposed that learning should be initiated with a posed problem such as a query or a puzzle to be solved. This will motivate learners to identify and research concepts which apply to these problems. Brown and King (2000) listed the common threads running through current literature on the principles of learning and components of problem based learning (PBL) instructional design as: 1. anchor all learning activities to a larger task or problem; 2. support the learner in developing ownership and control of the problem—also called activeness; 3. design an authentic task problem; 4. design the task and environment to reflect the complexity of the environment—also known as multiplicity; 5. give ownership of the solution process to the learner; 6. design the learning to challenge, as well as support, the learner's thinking; 7. encourage testing alternative views; and 8. ensure reflection on both the content and the learning process. The package tested here makes full use of the PBL approach allowing trainees to not only simulate the problem but to attempt to solve it in a "safe" environment where mistakes are not critical and costs of frequent attempts are not limiting. Such a principle was suggested by Kofman and Senge (1993) insisting that learning arises through practice and performance and is a proven strategy in workplace learning as demonstrated by Wang (2002). Thus the package takes on the role of instructor entering into a mixed media "dialog" with the learner so that they can gauge their current level of performance on a task and be advised on possible ways areas that need improvement. This concept of dynamic assessment was suggested by Holt and Willard-Holt (2000) and we believe underpins constructivist learning. Furthermore the supportive feedback created by the such assessment aids further development and encourages the learner to try further assessments and focus their development, stressed as good constructivist practice by Green and Gredler (2002). In addition the approach suggest that learners should be allowed repeated experience of different variations of the task adding to their index of knowledge (utilizing the “Variability Principle” van Merrienboer and Kester (2005)), with the active engagement reinforcing learning process.

In encompassing these features, designers of e-learning packages also need to be mindful of the usability of the software. Since the learners are using the package autonomously and asynchronously the interactive features need to be intuitive and kept relevant to the learning process. Designers must employ all the principles of user centred design. Greitzer (2002) reported that many e-learning applications employ state of the art multimedia and interactive technology but fail to meet their expected training potential. This can be the result of poor design, organisation of the content or usability, leading to the cognitive ability of the learner being compromised. Cognitive theories state that human memory is comprised of very limited working memory (Miller 1956) yet unlimited long term memory (Atkinson and Shiffrin 1968) however associated and organisational processes play an important role with the exploitation of relationships between items being used to assist learning (Anderson and Bower 1973). If knowledge is presented in an unordered or confusing way or the e-learning package is difficult to use cognitive load will be high. Thus e-learning systems must constantly strive to provide learners with interfaces that keep cognitive load low as well as engage the learner relevant material. Thus Carroll suggested that the most effective approach is to encourage learners to work immediately on meaningful, realistic tasks within a user friendly environment; to reduce reading time and passive activity; take advantage of prior knowledge and allow mistakes to be pedagogically productive. (Carroll 1987; 1990)

This study examines the use of simulation embedded in constructivist learning theory to empower computer interaction in assisting cognition. We assess both the effectiveness of the approach as well as the learners' perceptions of the usefulness of the package.

The Problem

Meat from the domestic pig (Sus scrofa) accounts for 42% of consumption worldwide and thus improvement of prolificacy in pigs is a critical objective of the meat producing industry. There is a pyramidal structure to pig breeding in most developed countries, in that most or all piglets are the direct descendants of a small number of boars. Therefore fertility problems in individual sires are likely to have significant, adverse effects on pig production. Pig semen is analysed at artificial insemination centres for concentration, morphology and motility however these parameters show only a weak correlation with prolificacy. Boar fertility is usually deduced from "none-return rates" i.e. the proportion of sows that do not return to heat divided by the total number of sows served by a particular boar. These figures are often only gathered towards the end of a boar's reproductive life by which time they may have already passed on any fertility defect to their sons (Sygen International, personal communication; Popescu et al., 1984; Quilter et al. 2002; http://www.pig-genetics.co.uk/breeding.htm).

The weight of evidence suggests that the most common cause of reduced fertility in boars is chromosomal abnormality i.e. a gross rearrangement of the genome (chromosomes) that can be picked up by microscopy analysis. In a series of studies, Ducos and colleagues (e.g. Ducos et al., 1996; 1997; 1998a,b; Pinton et al., 2000) using strictly determined criteria for none-return rates suggested that around 10% of boars are hypoprolific and that approximately half of these carry such an abnormality emphasizing the need to screen for it beforehand. Such analysis however has a number of drawbacks in that it is perceived to require highly skilled individuals and relatively few people therefore take the time to learn it. Further the cost of training is very high due to cost of laboratory materials and the infrequency of specialist courses and instructors. Alternatives include sending samples to specialist laboratories for analysis however this can have both cost and ethical implications. Moreover we are aware of only one laboratory (in France) that specialises in such analysis in pigs (Ducos, personal communication). In our view the solution lays in the education of individuals in performing analysis of pig chromosomes (so-called “karyotpying”) which involves sorting the chromosomes into recognised pairs and then assessing if any of the chromosomes look different from normal by comparing the chromosomes in each pair with each other, using computer-based simulations. These have gained in popularity in many fields of education including the replacement of “wet” student practical classes (e.g. Dewhurst et al., 1994; Gibbons et al., 2004; Heerman and Fuhrmann, 2000; Hughes, 2000; Leathard and Dewhurst, 1995; Maury and Gascuel, 1999; Modell, 1989).

In a previous study (Gibbons et al., 2003) we reported the development of a computer-based tutorial (KaryoLab) to teach to undergraduates similar “karyotyping” analysis of human cells. Development of this work established that this was an effective tool in undergraduate practical classes (Gibbons et al. 2004). In the current study we demonstrate that the adaptation of this programme for the analysis of pig chromosomes has a practical application in the workplace. Employees of a pig breeding company were tested for their skills before and after the tutorial to establish whether the "Karyotyping" skill could be learned easily and their opinions were assessed.

Methods

Development of tutorial programme

The programme itself "KaryoLabPorc" was written in a virtual lecture interface designed in Macromedia Authorware 6.5, an icon based multimedia development application. It was based on a previous programme "KaryoLab" (Gibbons et al., 2003; 2004) but contains pig chromosomes and a much more extensive tutorial section, the purpose of which was to replace the face to face lecture given to the students on karyotyping skills. The main menu consists of 4 topics ("Background", "Tutorial", "Practice" and "Assessment"), with each of these leading to further sub-topics. Navigation into the background topic leads to 4 sub-topics, "Hypoprolificacy", "Abnormalities", "Translocations" and "Preparation". From these sub-topics, written information is given about hypoprolificacy (similar to the introduction of this paper), its causes from a chromosomal standpoint and the nature of chromosomal abnormalities.

The "Tutorial" section is divided into further sub-topics that are named as follows: "Before Starting", "Grouping", "Group A", "Group B", "Group C", "Group D" (representing the classes of chromosomes that are analysed), "Problem Cases", "Abnormalities" and "Having a Go". These sub-topics collectively provide an introduction to how to analyse chromosomes and an explanation of how the program works. Examples of images of chromosomes and tips on how to perform the karyotyping are given.

The “Practice” section allows the user to practice the skill of chromosomal analysis in an interactive way. Five different karyotyping scenarios are available to the user and all involve a series of individual chromosome Adobe Photoshop images prepared from samples. Operators are requested to pair the chromosomes using a drag and drop function to manipulate chromosome images into “bins” that represent the appropriate place. Formative feedback is given in the sub sections entitled “karyotypes 1, 2 and 3”, that is, if the chromosome is dragged to the incorrect place, the chromosome will automatically return to its original position. A summative assessment is enforced in the sub sections entitled “karyotypes 4 and 5”, that is, the chromosome stays where the user puts it and, when he or she is finished they can press a “mark” button that instructs the computer to give feedback on whether the chromosomes were placed correctly.

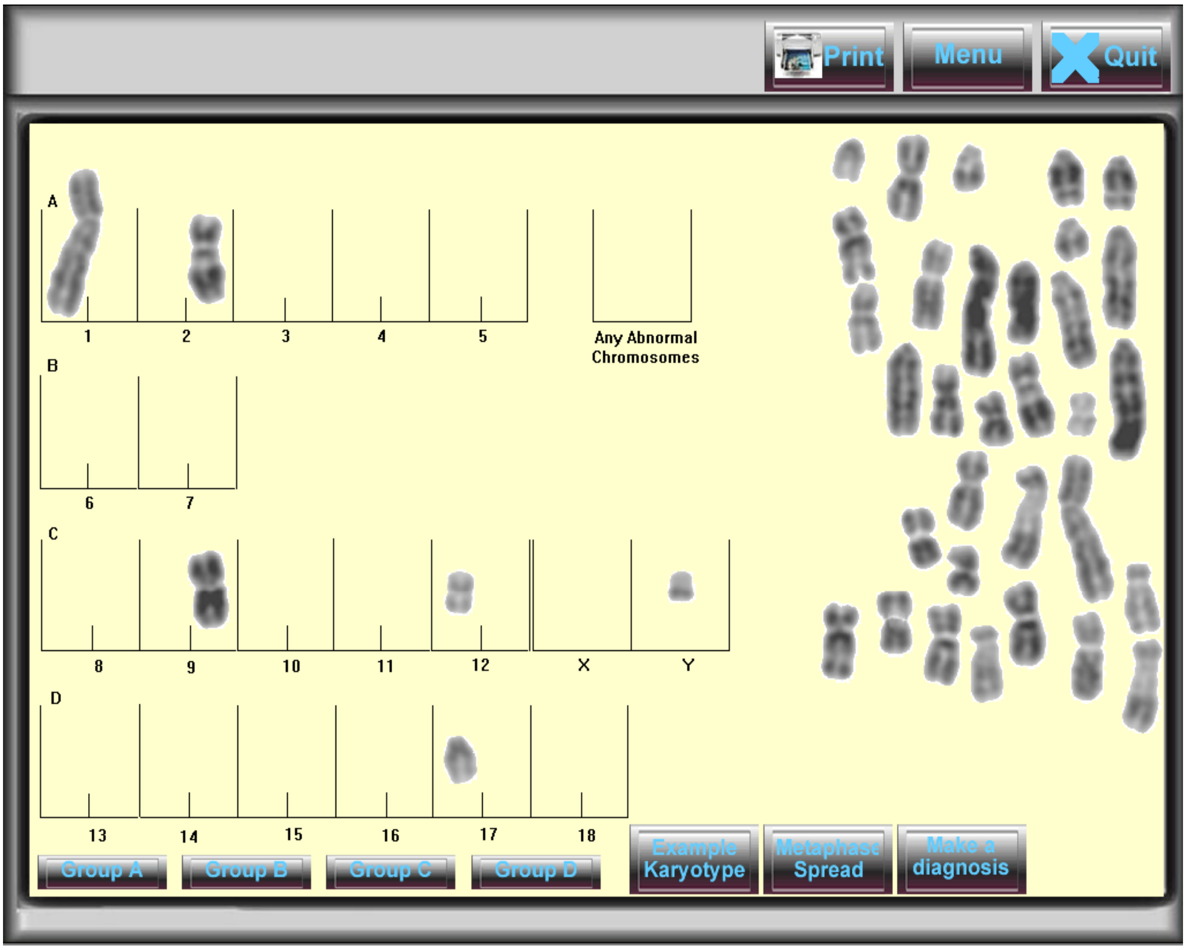
After completion of each exercise the user can then proceed to “making a diagnosis” – here they are asked whether any of the chromosomes they have paired are normal or abnormal and, if the latter, which chromosomes are involved; in this section they are instantly told if they are correct or incorrect. If help is required, at any point during this section the user can return to the tutorial section e.g. to examine the banding pattern of a particular representative chromosome.

The “Assessment” section is similar to the “Practice” session. It includes five different scenarios, (some of which are normal and some of which have examples of chromosome translocations taken form the literature) however, the computer does not provide formative feedback. On completion each exercise, the user then proceeds to “making a diagnosis” where similar questions are asked. Summative feedback is given only at the end of the process when the user is given a breakdown of their assessment score.

Study design

For the purposes of this study a case study design was used. Twenty five male employees at PIC International (http://www.pic.com) were approached and consented to take part in the study and to do the tutorial. Before embarking on this, they were tested for their karyotyping skills by a separate "Assessment" section similar to the "Assessment" section contained within KaryoLabPorc (described above) but containing different chromosome examples. This allowed a direct comparison of the extent of their skills before and after doing the tutorial. In addition they were asked to complete a short questionnaire pre- and post the experience. The pre-questionnaire targeted personal information and their attitudes towards computer based learning while the post-questionnaire targeted their feelings towards their achievement to the assessment and whether this was attributed to the KaryoLabPorc program. In addition, participants were also invited to provide any additional feedback towards KaryoLabPorc.

Below is a screen shot from the program.



Results

Pre and Post Tutorial Marks

A total of 22 out of 25 users completed the exercise with the remaining three only completing it partially (their results are not included). A mark out of 38 was given (one for each chromosome placed correctly) for both pre- and post- tests. The mean mark for the 22 users for the pre-tests (2 exercises) was 12.0 (31.57%). The mean mark (out of 38) for users doing the five exercises in the "Assessment" section after the tutorial was 27.8 (73.3%). This represents a significant increase of over 42% or nearly 2.4 fold ($p<0.01$ - Student's paired t-test). When asked whether the interpretation was normal or abnormal, the 22 users (for two exercises i.e. 44 possible responses) gave the correct answer 27 times (64%) - this is not significantly greater than the 22 (50%) than would have been expected by chance alone (chi-square test). In contrast, post-tutorial, there were 90 correct answers out of a possible 110 (22 users doing five karyotypes) a significant difference ($p<0.001$) from the 55 (50%) that would have been expected by chance (chi-square test). Finally, when asked to correctly identify the chromosomes involved, users were correct 0% of the time pre-tutorial and 21% of the time post-tutorial.

Results are summarised in table 1.

Table 1. Scores pre- and post-tutorial

	Mean score for Karyotype	% correctly spotting that an abnormality was present	% correctly identifying both chromosomes in the translocation (if present)
Pre-test	31.57%	64.0%	0%
Post-test	73.3%	81.8%	20.9%

Pre and Post Questionnaire Feedback

The pre and post test questionnaires consisted of a combination of sections which targeted a variety of information (tables 2 and 3 summarise the results from the personal opinions section). All participants had no previous experience of chromosomal analysis. When asked to classify their computer skills 68% (15) said they were “good” and 32% (7) classified them as “average”. When asked whether their achievements in pig karyotyping could be attributed mainly to the program, 16 (72.7%) agreed, 5 (22.7%) had a “neutral opinion” and one (4.55%) disagreed. Another noteworthy finding of this study is that a combination of questionnaire results and assessment marks gave no indication that the performance, in either pre or post tests, were related to the prior assessment of the participants computer skills.

When asked about what they thought about using the package 95% of the participants said they found the package easy to navigate and enjoyed the realism of the simulations. They were surprised how easy the process was to learn in the simulated environment. They particularly enjoyed learning when and where it suited them and commented that it was good be able to make any mistakes in the practice sessions in private avoiding the embarrassments they normally encountered in a traditional classroom setting. Many also said they enjoyed learning at their own pace and not having the added pressure of having to keep up with other members of a cohort. Participants also commented that the way the package was organised, as a series of problems to be solved, motivated them to learn and encouraged the participants to engage with the software much more than if the content was static pictures and text. When asked if they would enjoy learning other skills in a similar way the overwhelming majority said they would. Table 2. Table showing pre-test questionnaire opinions (Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), Strongly Disagree(SD)).

Question		SA	A	N	D	SD
PRE TEST						
A	Learning from computers is boring	0	1	10	11	0
B	I prefer to learn from books rather than a computer program	0	4	12	6	0
C	I cannot learn as much from a computer-based simulation as I can from books	0	5	13	4	0
D	I am worried that I will not be able to use this technology	0	3	4	15	0
E	Computer-based simulations are not as good at presenting information as books	0	4	3	15	0
F	A computer-based simulation will be an effective way to learn the skill of karyotyping pig chromosomes	0	14	8	0	0
G	I prefer to be taught karyotyping using a microscope and printed notes	0	7	8	7	0
H	The idea of using a computer-based simulation to learn this skill is appealing	0	15	6	1	0
I	I feel karyotyping is a specialised skill I would find difficult	3	13	6	0	0

	to perform reproducibly					

Table 3. Table showing post-test questionnaire opinions (Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree).

Question		SA	A	N	D	SD
POST TEST						
J	I am pleased with my assessment grade	0	10	11	1	0
K	I feel my achievement can be attributed mainly to my previous knowledge of karyotyping	1	1	1	19	0
L	I feel my achievement can be attributed mainly to the program	0	16	5	0	1
M	I feel I could have done better if I was more computer literate	0	1	21	0	0
N	Using a computer-based simulation allowed me to do it at my own pace therefore I feel my achievement was far more successful	0	9	12	1	0
O	Learning from computers is boring	0	0	22	0	0
P	I would prefer to learn from books rather than a computer program	0	0	20	2	0
Q	I cannot learn as much from a computer-based simulation as I can from books	0	0	13	9	0
R	I was not able to use this technology	1	0	2	19	0
S	Computer-based simulations are not as good at presenting information as books	0	0	18	4	0
T	A computer-based simulation was an effective way to learn the skill of karyotyping pig chromosomes	0	11	10	1	0
U	I would prefer to be taught karyotyping using a microscope and printed notes	0	1	15	6	0
V	The idea of using a computer-based simulation to learn this skill was appealing	0	7	14	1	0
W	I found the navigation around the program easy	0	21	1	0	0
X	I enjoyed the experience of computer-based learning	0	5	17	0	0
Y	I found it easier to learn from a computer-based simulation rather than from books	0	0	22	0	0
Z	The interface of the program was user friendly	0	12	10	0	0

Discussion

This study has shown that using e-learning best practice principles and a constructive learning approach, the complex and skilled task of chromosome analysis in boars can be learned by trainees with no previous ability. The package was designed to be learner paced and allow asynchronous learning of the contents often favoured by mature trainees with other constrains on their time. We made full use of the “Fidelity Principle” (van Merrienboer and Kester 2005) in making the tasks and test as realistic as possible using digital images of real chromosomes and known chromosomal aberrations. A problem based learning approach was adopted with the package encouraging the trainees to “Have a Go” at karyotyping and receive formative feedback before undertaking the summative test at the end of the exercise. The karyotyping problems were varied (adhering to the “Variability Principle” van Merrienboer and Kester 2005) to increase the trainees exposure to many different chromosomal abnormalities thus increasing their knowledge index.

This package uses the power of simulation to give the learner a near reality PBL experience. Many professions have successfully used simulation/simulators. The advantages are that they reduce cost and provide authentic scenarios to participants that would otherwise take years to experience, resulting in a better trained, more capable individual. Most have used simulations for a variety of reasons mostly to gain experience or practice a skill, but until recently, few have used simulation as a teaching tool (Smith and Boyer, 1996). The issue of computer simulations as adaptations for student practical classes however is increasingly apparent in the literature (e.g. Dewhurst et al., 1994; Gibbons et al., 2004; Heerman and Fuhrmann, 2000; Hughes, 2000; Leathard and Dewhurst, 1995; Maury and Gascuel, 1999; Modell, 1989). We show that this approach can be successfully transferred from the classroom to the workplace:

We have we previously compared karyotyping skills of undergraduates using human KaryoLab simulation e-learning package to using the traditional "scissors and glue" approach within the confines of a practical laboratory, supported by an appropriate lecture (Gibbons et al., 2004). In the current study, the “practical class” was taken out of the university environment and the lecture was replaced by a computer-based tutorial. The highly significant improvement in skills post- tutorial provides compelling evidence that the tutorial itself facilitated the learning process. Research into university practical classes (e.g. Dewhurst et al., 1994; Gibbons et al., 2004; Heerman and Fuhrmann, 2000), although usually performed on individuals who are 18 or over, essentially ask questions of pedagogy. In this study we propose that the question asked relates more to “andragogy” (Knowles, 1984) which has received relatively little attention in the literature compared to pedagogy. Knowles (1984) states that the more mature learner needs to know why they need to learn something and learn best when the topic is of immediate relevance to their job. Moreover adults need to learn by experience, partly from their mistakes and learn best when approach learning as a problem-solving exercise. This has been demonstrated by Ivancic and Hesketh (2000) in a driving simulation environment where they eloquently showed that making errors enhanced and increased the efficacy of the learning. In this study participants made less errors during real life driving after being allowed to make errors using the simulation. In this study we propose that we have developed an approach that incorporates all these principles. The package therefore demonstrates that the use of PBL and computer simulation is a powerful learning tool in the work place. It was equally crucial that the simulations reflected reality with an easy to use interface in order to facilitate to the learning process.

The ability of individuals in pig breeding companies to analyse boars with reasonable accuracy could have significant ramifications for improvement of prolificacy in the pig breeding industry as a whole. A conservative estimate is that that the UK pig breeding industry is losing around £9.5 million as a result of hypoprolific boars (Sygen International, personal communication) and therefore prolificacy could be improved dramatically as a result of education expedited, in part, by this e-learning package.

In principle, a set of the basic laboratory equipment required for chromosome analysis is easily acquired and many labs are already equipped with microscopes. It is also worth noting that, in clinical laboratories, it is essential for 100% accuracy in diagnosis as the consequences of failure could lead to misdiagnosis of a severely affected birth (Wolstenholme, 1992). In contrast, for boar screening, the consequences are financial and any relatively low-cost solution to even partly solve the problem would be an improvement on the status quo where, in many centres, no boars are screened at all (Popescu et al., 1984; Pinton, 2000). While in a clinical laboratory it is essential to look for very subtle aberrations (Wolstenholme, 1992) for boars, relatively overt and simple aberrations are common in sub-fertile boars (e.g. Ducos et al., 1996; 1997; 1998a, b; Pinton et al., 2000; Ducos, personal communication). Therefore, although chromosome analysis is a highly skilled pursuit in clinical laboratories, such accuracy is desirable though not essential for the screening for relevant abnormalities in boars therefore the use of less experienced staff is appropriate. In this study the experiments described here were performed on a series of "volunteers" who did the tutorials in their spare time. Despite this, they ultimately performed the exercises with a mean 73% accuracy and spotted the presence or absence of an abnormality with a mean 82% accuracy, a success rate more than adequate for pig breeding. Someone with responsibility to do this in a "real world" situation would perhaps spend more time honing their skills and increase these percentages further.

In conclusion we present a stand alone e-learning solution to the teaching of a complex task which at present is seen as too costly and specialised to be worth sending employees on a traditional training course to learn. The use of constructivism principles to aid its design, along with acknowledged e-learning and computer usability best practice demonstrates that this medium can be used successfully in the training of highly specialised and skilled tasks required in the modern workplace.

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