# INTERACTIVE GRAPHICAL TRAINING

# FOR

# WORKPLACE LEARNING

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A project submitted to the University of Dublin,

in partial fulfilment of the requirements for the degree of

Master of Science in Technology & Learning

2008

Declaration

I declare that the work described in this document is, except where otherwise stated, entirely my own work and has not been submitted as an exercise for a degree at this or any other university.

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# Abstract

The purpose of this study was to investigate the triangular relationship between adult learner, teacher and interactive graphical learning tools built on an ICT platform in a workplace environment. The working environment was an automated manufacturing plant and the context was technical training for operations workers. The artefact was a sequence of web-based interactive animation, creating a visual representation of the subject matter.

To promote learning interactions between the learner and the teacher, the design of the artefact adopted constructivist learning principles. The research questions centred on whether rich learning experiences could be mediated by the artefact, whether knowledge is constructed by the learner using the artefact and if the lesson promoted inquiry dialogue over didactic teaching.

The research was carried out with a group of skilled & semi-skilled workers, based in a beverage plant in Ireland, who work in cross-functional teams, operating and maintaining the equipment. The subject matter was specifically related to elements of their day-to-day jobs. Knowledge gaps were identified as good opportunities for research into improving training effectiveness. Specific functions associated with pasteurisation and filtration technology were selected on the basis of their complexity and the associated challenge to developing rich and meaningful learning experiences around them.

The research showed how interacting with the animations broke down barriers with the material, creating moments of intense dialogue between the instructor and learner around the subject matter and, consequently rich learning experiences for workplace learners. An initial period of passive observation followed by a more intense interactive session proved to be the best combination for the learner.

In addressing the research questions the research found evidence to suggest that understanding arose in the learner using the artefact rather than from demonstration by the trainers. Moreover, this process promoted a ‘learning together’ approach whereby the trainers were able to follow a line of enquiry using the artefact together with the learner rather than provide an answer for them. Thus inquiry dialogue was mediated by the animation tool.

As a result, the organisations local training group are looking at ways to apply this approach to future training events.

# Introduction

## Background

The use of symbols and graphics are common in teaching. Since the early '80's computers have been used to develop the efficacy of graphics in education. For the most part, this has been limited to didactic forms rather than an extension of technology as an enabler in itself. Certain exceptions arise within areas such as the military, aviation industry and surgical centres. The arrival of ubiquitous computing and low cost software has yet to deliver a similar selection of learning tools for a broader population of learners. We can see where attempts have been made in such industries as semi-conductor, medical and IT. Some researchers suggest the tools and processes have not as yet provided a compelling case for their widespread use in teaching & learning (C. D. Hundhausen, Douglas, S. A.,, 2000; Jarc, 1999). Despite this, the use of animation and simulation tools for workplace learning is on the rise.

## Semiotics and Enhanced Socratic Mode Teaching

Semiotics is defined as the role of symbols in society, ranging from oral to graphical and beyond to include sensory and semantic symbols. In the context of education, semiotic mediation refers to the use of symbols in the pursuit of knowledge and understanding. This dissertation is concerned with the use of technology-based graphical interfaces and how they can be successfully adopted as semiotic mediators for workplace learning. This case study shifts the focus to an industrial setting with vocational level training requirements. The background to Semiotic Mediation is explored below as is the phrase Enhanced Socratic Mode. The relationship between the teacher and learner is key to this research. While Socratic Mode teaching has been well documented, Enhanced Socratic Mode teaching applied to workplace training as facilitated through technology-based Semiotic Mediation, attempts to reveal a new and powerful training mechanism in a contemporary technological paradigm.

## Workplace Learning

Management gurus, academics and policy advisers across the developed world have insisted that higher levels of skills within the workforce are basic building blocks for the success of future economic development. This supposes the adoption of a new model, which moves economic activity into a new high skill, high performance model of working which will underpin the 'knowledge economy'. A review of the state of research into Vocational Education & Training (VET) by the EC in 1999 highlighted the need to further investigate the 'particular combination of education, training, employment and community which produce either exceptionally rewarding learning experiences, or a series of mundane experiences, leading to little learning' (Brown and Keep. 1999: 47). With the challenge of changing economic environment on the one hand, and the need for greater understanding of VET

outcomes arising from VET within the European Community, it is opportune to look creatively at the proposition of enriching workplace learning.

## Research Setting

The research is set in a beverage plant in the Republic of Ireland. Interactive Animated Training Modules (or IAT Modules) were developed to the author's specification by a professional multi-media designer. The design was based on two prototypes which the author had developed and evaluated. The final modules were custom-built for two training applications. The first was set in a production area which recovers beer from a brewers yeast suspension using cross-flow filtration technology. The second was set in a packaging area, associated with the shelf-life stability of finished beer using flash pasteurisation techniques. The target audience was comprised of the skilled and semi-skilled operators running the machines used for these purposes. The approach of the IAT Modules was based on constructivist learning principles

## Review of the Literature

A brief review of the literature was carried out to understand the current thinking regarding the application of semiotic mediation, constructivist learning, andragogy and Socratic dialogue. Relevant case work in the field was examined. From this, research questions were compiled which could support or challenge current thinking and provide more insights into the application of graphical simulations as constructivist learning tools in workplace learning. The design and methodology of the research was constructed in an attempt to answer these questions.

## Design

The research activity was designed around an interactive graphical animation sequence. Early prototyping provided the basis for final design in consultation with the local training group. This was imbedded in a web-based environment. The artefact was developed to initially provide a series of low level exercises followed by a higher order investigation, finishing with checks for understanding.

## Research Methodology

The research methodology employed was a case study. A sample group was provided with an overall package which included the interactive animation, instructional material for use by trained trainers, support material in the form of worksheets and checks for understanding in the form of training evaluation and feedback forms. The material was structured in such a way as to encourage contributions from the learners. Learning experiences were recorded on video. Research data was triangulated with semi-structured interviews, research questionnaires, researcher observation journal and expert opinions.

## Findings

The research revealed an overwhelming engagement with the material. The extent to which the artefact stimulated the participants' appetite for the both the visualisation and the interaction was hugely underestimated. The trial performed strongly across all areas of enquiry and a vibrant learning experience emerged. The triangulation of data through video, interview and written feedback clearly identify mediated learning with emergent higher order thinking. This was underpinned with continued and focused dialogues among the participants and with the teacher.

## Discussion

The artefact created immediate interest and stimulated inquiry into the content. The success of the initial opening moments produced a momentum which carried through the trial. While the participants suggested a number of improvements in the evaluation, these were relatively minor augmentations, and if anything suggest a proliferation of the approach to other areas of interest for the participants. In observing the process, certain aspects became self-evident;

- Success depended on blended learning environment
- Use of the tool requires its own skill.
- Prior knowledge of the participants was essential
- Epistemic fidelity was important to the participants
- Expert others within the participant group were important
- Interactivity with the artefact provided the impetus for learning

## Conclusion

The artefact was successful in introducing both interactive animation as a training tool in a workplace environment and, through it, mediated learning dialogue as a successful workplace training strategy. While of themselves, graphical teaching aids and learning dialogues were not new to the workplace technical training group, the 'wow' factor produced through the use of the interactive animation created the breakthrough for rich learning dialogue in a way that pushed the content of the discussion into previously unexplored territory. What ultimately emerged from this piece of research is the effectiveness of the relationship between the student, the teacher and the artefact when the interdependent enhancements of constructivist learning, semiotic mediation and Socratic methods are successfully employed.

The overall experience was deemed a success for the participants and provided interesting insight into the specific opportunities and challenges for workplace learning in that particular location. Further research in this area would be required to understand and develop the potential of this approach and fully explore the interdependent nature of constructivist learning, semiotic mediation and Socratic methods when they are applied to a broader workplace learning context.

# Review of the Literature

## Introduction

By way of introduction, it is important to consider the roots of adult learning. Ancient civilizations developed different processes for teaching than the familiar schema in mainstream education today. They were concerned primarily with adult learning. They were built around learning as a process of enquiry as opposed to the delivery and reception of content. Accordingly they developed ways of engaging learners in enquiry based techniques.

Ancient Chinese and Hebrew culture features a style of teaching sometimes referred to as 'case method', where one described a situation, and together with the group explores its characteristics and possible resolution (Pekarsky D, 1994). Ancient Greece features what we now call the Socratic Dialogue, a type of structured questioning process in which one poses a question or dilemma and the group pool their thinking and experience to seek an answer or solution.

In the 7th century, schools were organized to prepare children for priesthood, giving rise to cathedral and monastic schools. Out of this came a set of assumptions about learning and strategies for teaching that became labelled as pedagogy.

These organizational models persisted well into the 20th century. In America, the study of adult learning re-emerged with the formation of the American Association for Adult Education in 1926. Two streams of investigation commenced at that time; a scientific approach led by Edward Thorndike (Adult Interests,1928) and an intuitive/reflective approach led by Eduard Lindeman (The meaning of Adult Education, 1926).

In the late 20th Century, pedagogy has received greater focus as the knowledge economies of the west looked to the educational establishment to support its progress. As we enter the 21st century, andragogy is receiving similar treatment. Greater volatility in the workforce, the prospect of longer working lives, up-skilling and retraining for business and individuals are among the emerging educational challenges for western societies. The rise of technology in workplace learning is a pivotal development. (Is mot on-line training the most common use in the workplace.) The advent of powerful computer graphics platforms has enabled a new era of visualization material for training and education. Workplace learning has certainly benefited by operational insight provided from such tools as flight simulators, cut-away animations and film clip style sequence demonstrations. High cost, high risk industries such as munitions, surgery and aviation have successfully incorporated these training tools into their ways of teaching and learning.

However, within mainstream industries such as manufacturing, instructors claim the animations are too expensive and not educationally effective. ["Toys for big boys"](C. Hundhausen, Douglas, S., Stasko, J.,, 2002). In cases where the use of animations competes with traditional teaching methods, there is limited scope for additional learning. While the animations are fascinating and even

entertaining to the target audience, the substantive content is either too trivial (and easily been taught through more traditional means e.g. chalk & board) or too complex. There is a premise that in learning pictures are superior to words. However, in an effort to truly represent the subject matter, animations can cause graphical information overload resulting in cognitive overload. This raises the question of how to evaluate such a scenario, other than anecdotally, and how the outcome of such an evaluation can be used to inform the design of animations used for learning purposes, and while animations for teaching and learning are certainly gaining some ground, the industrial complex has yet to move en mass to adopting this approach.

This chapter will attempt to shed some light on the issues surrounding computer animation & simulation in the context of workplace learning, understand the reasons behind these issues and aggregate selected theory for future design to improve learning outcomes. It sets out to look briefly at background theory, goes deeper on relevant specific theory and then narrows the focus to the particular areas of interest to the researcher. Having looked at these it broadens out to cover some of the lessons learned from more recent work and goes broader again to pick up on certain developments in the field.

# General Theoretical Background

## Adult Learning

As noted above, the field of andragogy is less developed than the field of pedagogy. Since the early days, adult educators have debated what adult education really is. It has alternatively been described as a set of guidelines (Merriam, 1993) a philosophy (Pratt, 1993) a set of assumptions (Brookfield, 1986) and a theory (Knowles, 1989). Here, the view is taken of andragogy as a set of learning principles which apply to all adult learning situations (Holton & Swanson, 2005). Malcolm Knowles (Knowles, 1980) made five assumptions about the characteristics of adult learners which distinguish them from child learners on which traditional pedagogy is premised. These help shape our perception of authentic adult learning situations. Knowles five assumptions are as follows;

- Self-direction; as a person matures their self concept moves from one of being a dependent personality toward one of being a self-directed human being.
- Experience as a resource for learning; as a person matures they accumulate a growing reservoir of experience that becomes an increasing resource for learning.
- Roles in society as drivers for learning; as a person matures their readiness to learn stems increasingly from the developmental tasks of their social roles.
- Orientation to learning; as a person matures their time perspective changes from postponed application to immediate application. Accordingly their orientation toward learning shifts from subject-centred to problem centred.

- Motivation to learn; as a person matures the motivation to learn shifts from external drivers to internal drivers.

These assumptions continue to be the subject of hot debate. Merriam and Caffarella (Merriam, 1991) have pointed out that Knowles' conception of andragogy is simply an attempt to build a comprehensive theory (or model) of adult learning that is anchored in the characteristics of adult learners. As such, it is considered here as a guide rather than a formula for design or a statement of fact. To complement Knowles assumptions, the work of Carl Rodgers (Rodgers, 1969) of the Association of Humanistic Psychology provides another point of reference. Rodgers suggested the following;

- Personal Involvement; the whole person including feelings and cognitive aspects are involved in the learning event.
- Self-initiation; even when the impetus or stimulus comes from the outside, the sense of discovery, of reaching out, of grasping and comprehending, comes from within.
- Pervasiveness; learning makes a difference to the behaviour, attitudes, perhaps even the personality of the learner.
- Evaluation by the learner; the learner knows whether the learning meets their personal need. The locus of evaluation rests firmly on the learner.
- Its essence is meaning; when such learning takes place the element of meaning is built into the whole experience.

Rodgers work helps to focus on the psychology and motivations of the adult. Taking a step deeper, Maslow (1970) considers the goal of learning to be self-actualization. He sees learning in the context of growth towards this goal as being defined by two sets of forces; one set clings to safety out of fear, the other drives forward toward wholeness of self. *"We grow forward when the delights of growth and the anxieties of safety are greater than the delights of safety and the anxieties of growth"*(1972 p 44-45). We might interpret this as the delight of learning and the anxieties of ignorance must be greater than the delights of ignorance and the anxiety of learning for an adult to engage in a meaningful learning experience. Within this insight, there is an opportunity to delight the learner while providing reassurance with a safe environment.

## Constructivism

To research and develop a constructivist learning experience, it is necessary to review the roots of constructivism. In 1952, Jean Piaget articulated mechanisms by which knowledge is internalized by learners (Piaget, 1952). He suggested that through processes of accommodation and assimilation, individuals construct new knowledge from their experiences. Constructivism describes how learning should happen, regardless of whether learners are using their experiences to understand existing content e.g. listening to a lecture, or attempting to create new outcomes e.g. designing a model aeroplane. In both cases, the theory of constructivism suggests that learners construct knowledge. Cognitive constructivists such as Glaserfield posit learners actively construct new understanding by

interpreting new information or environments with reference to what is already known (Glaserfield, 1989). This is important in the context of Knowles' 2nd assumption of an adults experience being a resource for learning. In the context of the workplace, this experience becomes a keystone for constructivist learning.

## Social Constructivism

Social constructivism encourages the learner to arrive at his or her own version of the truth, influenced by his or her background, culture or embedded worldview. Symbol systems, such as language, logic, and mathematical systems, are inherited by the learner as a member of a particular culture and the nature of the learner's social interaction with knowledgeable members of a group or society plays an important role in how these are adopted. In the absence of social interaction with other more knowledgeable people, it is impossible to acquire social meaning of important symbol systems and learn how to utilize them (James V. Wertsch, 1997). In the context of workplace learning, these social symbol sets act as an overlay on the formal content-based symbol sets. Naming conventions, references, signifiers and language are adapted by the social groupings in the workplace. Some naming survives and persists within the workplace but this is case dependant. More naming is mildly adapted and some is radically changed. The resulting hybrid systems can vary hugely depending on the variation and social complexity within the workplace. Thus the realization of learning outcomes can vary from one workplace to another.

## Semiotic Mediation

Most social constructivist models stress the need for collaboration among learners. The zone of proximal development is the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem-solving under guidance or in collaboration with more capable peers. Through a process of 'scaffolding' a learner can extend the learning process (L. Vygotsky, 1978). Vygotsky's ideas about the zone of proximal development are extended by the inclusion of Semiotic Mediation. Its incorporation into human action is not simply more efficient in a quantitative sense, but also results in a qualitative transformation. In his view 'by being included in the process of behaviour, the psychological tool [sign] alters the entire flow and structure of mental functions. It does this by determining the structure of a new instrumental act' (Vygotsky 1981a: 137). However, in putting forward the concept of semiotic mediation, Vygotsky attached greater importance to language than he did to other modalities (L. S. Vygotsky, 1962) (J. V. Wertsch, 1985). Language has been granted this special status in Vygotsky's theory, implying that language enables us to do that which other modes do not (Hassan).

# Specific Theoretical Areas

## Visualisation & Recall

There is some historical evidence to support the claim, ‘a picture paints a 1000 words’. Pictures have a tighter locus of understanding than text reducing overall cognitive overhead. Studies carried out as early as 1894 (Kirkpatrick, 1894) demonstrated improved recall when subjects were presented in word and in picture form compared with word form only. In the 1970’s , Standing measured a recall rate better than 95% on lists of 10 to 10000 complex pictures and found subjects were able to recall subsets of these pictures with 95% accuracy (Standing, 1973).

Paivio’s dual coding theory (Paivio, 1991) posits ‘an orthogonal relationship between symbolic systems and specific sensor-motor systems’. Verbal and non-verbal codes can be active in parallel and cross reference each other. These can have an additive effect on recall. This is in contrast to verbal-verbal or picture-picture representations.

Nelson’s sensory-semantic model (Nelson, 1977) is based on three assumptions. Both pictures and words access a common semantic code, pictures access phonemic information about the verbal labels and that while pictures and words differ in their physical and sensory features, pictures are more discernable than words.

Andersons tri-code theory (Anderson, 1978) posits three codes as opposed to Paivio’s two code model. The three are a temporal code, a spatial image and an abstract proposition (ATS Theory). He claims that it is impossible to identify whether a particular notation correctly expresses the structure. He argues the value of a certain representation will depend on issues of processing efficiency, and not on the representation itself.

## Workplace Learning

Workplace learning provides a setting where the construction of knowledge is mediated by social and cultural circumstances in which the knowledge is experienced (Lave, 1990, Rogoff, 1990, Scribner, 1985). It follows that the authentic nature of the activity and circumstance assist the development of knowledge and its transfer. Consequently, development of vocational knowledge is aptly suited to the workplace and this is an authentic setting for its development (Scribner, 1992). Stephen Billet proposes a subset of attributes to characterize workplace learning. These are as follows,

- Authentic activities; opportunities to engage in occupational tasks within their applicable context.
- Expert others; assistance with initial approximation, modelling, coaching, support and sequencing to assist skills development.
- Other workers; indirect guidance through observation, listening and role modelling.
- Engagement in tasks; active and constructive engagement in learning task arising from relevance.

As a counterpoint, Billet suggests factors which may have a negative impact on workplace learning;

- Undesirable knowledge; incorrect practice unchecked giving rise to inappropriate outcomes.
- Access to activities; development limited by paucity of experience.
- Reluctance and/or absence of experts; reducing the possibility of guidance, coaching and support.
- Opaque knowledge; conceptual knowledge impenetrable to the novice.
- Instructional media; knowledge format disembodied from the activity.

Billet draws on a range of works to support his proposition (Billet, 2001) and this provides an important insight to appropriate design for workplace learning activities. Specifically, Billet warns of instructional media falling into the trap of "providing training solutions which are unlikely to develop the rich array of knowledge types required for complex performance". However, he concludes the qualities of workplace learning most likely to secure effective knowledge transfer have structured activities to assist individuals. Further, they must provide expert guidance pressing individuals to access more complex knowledge and effectively illuminate that which is not readily revealed.

## Learner-Centred Environments

The focus of mainstream educational curricula has historically been on content and its delivery. Subjects are broken down into smaller, more manageable subtopics and taught in the classroom (Pea & Gomez). On the other hand, the movement toward "learner-centred education" focuses on the needs of the learner. While the success of "learner-centred education" does not rely on technology, electronic learning environments serve as a powerful catalyst for change. These environments include:

- 'collaboratories' that facilitate group communication,
- construction toolkits that teach design and modelling skills,
- systems with "scaffolding" that allow learners to start simple and build complexity, and
- simulations that support "learning by doing".

Research has been carried out in the area of algorithm visualisation which provides insight into the effectiveness of learner-centred environments using interactive graphical animation tools. In 1999, Byrne carried out a study entitled 'Animations as Student Aids in Learning Computer Algorithms'. The research defined two specific learning events:

A: The learner centred event; is described as an event where the learner's involvement was the primary consideration - i.e. the design focused on how the learner would interact with the material.

B: The material centred event; is described as an event where manipulation of the presentation was the primary consideration i.e. the design focused on the range and extent of material which could be displayed.

Using traditional methods of teaching computer algorithms as a datum, the ‘Learner Centred Event’ showed a very significant (71%) improvement over the datum in educational effectiveness, whereas the ‘Material Centred Event’ showed only a 33% improvement (Byrne, 1999; Lawrence, 1994). This suggests the simulation technology can have a greater impact if it is specifically designed to engage the learners rather that focus solely on replicating the process. As any design process inevitably requires compromise, the study suggests the learning outcome is better served by facilitating learner engagement.

# Key Areas of Interest

Much of the research dealing specifically with semiotic mediation and enhanced Socratic teaching methods using interactive graphical animations has been in the field of Algorithm Visualisation. This dissertation draws on that research to build on its success and inform the design and delivery of a parallel approach into workplace learning in an industrial context.

## Dialogue

Central to the research is an understanding of how the dialogue between teacher and learner can be supported. A brief review of the literature reveals some interesting insights into the contribution of dialogue to the learning experience. As discussed above, the social constructivist view of Wertsch, Vygotsky et al requires a social interactive component to the lesson plan. Furthermore, the importance of language, not only in theories of recall, but also in Vygotsky's treatment of Semiotic Mediation, requires a strong verbal component to the lesson structure. In his research, Hundhauser prevented self-constructing learners discussing with either peers or experts. He concluded that, as a consequence, learners could not build upon or modify their understanding (Hundhauser, 2002). Grissom supports Byrne (Grissom, 2003) by offering that simulation technology is best employed in a scaffold learning environment where learners are allowed to correct their misunderstandings through discussion and interaction with fellow learners and instructors, and concurs with social constructivism as described by Vygotsky et al.

## Epistemic Fidelity

Epistemic fidelity assumes graphical representations are endowed with an ability to support an expert's mental model of a domain or process. This suggests the higher the fidelity of the match, the more efficient the transfer of knowledge to the viewer of the visualization (Roschelle, 1994). Larkin and Simon analyzed verbal and schematic representations (Larkin, 1987). They compare the role of diagrammatic representation (the components of a diagram describing a problem) and linguistic representation (the components of a verbal description of a problem) in three cognitive processes, namely search, recognition and inference. While there is equivalence between the two types of representation across the three cognitive modes, they found the retrieval from linguistic representation required a linear path through the material while the non-linear feature of diagrammatic representation provided a tighter locus of information allowing faster retrieval. While Larkin and Simon deduced the difference on inference was less dramatic, Bauer and Laird found that diagrams aid inference by making alternative possibilities more explicit (Bauer, 1993).

## Interactivity

It is certainly possible to include a wide range of functions and features when designing animated educational tools. The question for the designer is which ones will deliver the best learning outcomes. Brown's Balsa system, designed for algorithm visualization, presented multiple graphical representations and exposed properties and behaviours that might otherwise be difficult to understand or remain unnoticed (Brown, 1988). Features were added to the design model for instructive animations including multiple concurrent views, colour coding, smoothing of execution, sound, 3D modelling and player controls to pause/rev/ff. However, the overall effect of the passive animation was found not to lead to significant improvements in a learner's understanding. Beneficial effects were lost without teacher accompaniment. Inability to interact with the material limited the learner's ability to exercise higher order thinking skills.

To understand and codify learning outcomes, we can use Blooms taxonomy as it might apply to workplace learning using graphical animations (See Appendix E2). Passive animations satisfy Blooms Level 1 (Knowledge) and Level 2 (Comprehension) (Bloom, 1972). They enable learners to recall basic facts. They further enable learners to discern some meaning of the basic functions. However, these represent the lower levels of understanding and Bloom's taxonomy applied to learning animations requires them to be interactive, if they are to used to promote Higher Order Thinking Skills (Bloom, 1972). Jarc found learners were unable to replicate the behaviour of a process, despite stating emphatically that they understood it after simply viewing an interactive simulation (Jarc, 1999). The design of such artefacts must therefore move beyond epistemic fidelity and consider a more constructivist approach. Grissom found that as the level of learner engagement with the simulation increased, so did their understanding (Grissom, 2003). Stasko found learners who constructed their own understanding of a process using an interactive computer program had a better understanding than those that did not (Stasko, 1997).

## Combined Dialogue, Epistemic Fidelity and Interactivity

Hundhauser demonstrates the consequences of poor dialogue and social constructivists, such as Wetsch and Vygotsky, make a clear case for active and vibrant dialogue. Rochelle, Larkin and Bauer et al make a clear case for high quality graphical representation of the content. The work of Brown, Jarc and Grissom suggest interactivity is necessary to further enhance a social constructivist learning experience using technology based mediators e.g. graphical animations. These ideas of dialogue, graphics and interactivity form the core area of academic interest of this dissertation .

# Lessons learned from recent research

## Unintended Uses

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

## Ethics of pure Socratic Dialogue

While dialogue of itself has been explored above as a positive contribution to a constructivist experience, the application and consequence of a Socratic Dialogue in a constructivist setting is less well understood. Daniel Pekarsky (Pekarsky D, 1994) scrutinizes "Socratic teaching", with attention to desirability of purpose, its probable effectiveness and its ethical status. He highlights the teacher's effort to guide the student from complacently held opinion to a state of humility and perplexity, in the belief that this will contribute to the student's development. This is accomplished through a process of questioning where the student is brought to recognize that his or her belief-system is riddled with inconsistencies. This approach is at odds with Maslow's observation of the psychology of the adult learner. The "delights of safety and anxieties of growth" posited by Maslow would likely be in evidence and thus inhibit learning. In the opinion of this author, purist Socratic Dialogue would be both impractical and unethical in the context of workplace learning.

## Suitability for novice learners

Some studies have show increasing the level of learner involvement did not always produce improved educational effectiveness. New learners struggle in the absence of a foundation upon which to map the apparent logic of the process to that of its graphical counterpart. Kirschner et al (Kirschner, 2006) argue that "learning by doing" is useful for more knowledgeable learners, but not for novices because they promote behavioural activity too early in the learning process. Mayer too, is concerned with discovery-based teaching techniques, quoting a study of students working on solving mathematics problems where the student performed better when they studied worked-out examples rather than when solely engaged in hands-on problem solving (Sweller, 1999). Mayer is unequivocal. "Today's proponents of discovery methods, who claim to draw their support from constructivist philosophy, are making inroads into educational practice. Yet a dispassionate review of the relevant research literatures shows that discovery-based practice is not as effective as guided discovery" (Mayer, 2004).

While both Kirschner and Mayer provide neither an exhaustive basis for their propositions, nor relate specifically to adult learning or workplace learning, their insights should not be ignored.

# Specific developments in the field

## Facilitated prediction

Conceptual knowledge can be defined as the understanding of the abstract properties of a process or operation. Procedural knowledge can be defined as an understanding of the procedural step-by-step behaviour of a process (Lawrence, 1994). Byrne found one way in which animations may aid learning of procedural knowledge of a process is by encouraging learners to orally predict the processes behaviour (Byrne, 1999). A similar learning improvement was found when learners made predictions using diagrams. This suggests prediction facilitates learning effectiveness. Jarc automated the prediction process in a web based application and found no significant improvement. However, he postulated and subsequently successfully tested the theory that poor learners used the automated prediction process as a game and thus tended to 'have a guess' rather than apply reason. Correct use of the facility thereafter did improve the effectiveness scores, highlighting the importance of scaffolding the use of simulation based learning.

## Extraneous Cognitive Load

Pea and Gomez found that commercial simulation packages (e.g., Excel, Matlab, and VisSim$^{TM}$) are built to handle a variety of situations so they provide generic user interfaces. These packages of themselves required training. Their research showed a negative effect arising from the additional training requirements and expressed this in the form of distraction from the core learning. The additional cognitive load arising from the unfamiliar interface limited the effectiveness of the tools as mediators for learning.

## Instant Feedback

M. Brezis and R. Cohen (Brezis M, 2004) test this as a way to maintain attention and to promote changes in behaviour. They employ active learning, which stimulates the audience to think and participate. They employed a technology platform where audience's answers to questions were displayed, providing instant feedback to both lecturer and audience, and promoting the use of case discussions and problem-solving exercises. They posit this modality improves the quality of clinical learning.

# Summary and Research Questions

In the context of industrial settings, interactive graphical animations used for workplace training tend to suffer from the combined effect of the following deficiencies;

a) An underdeveloped model of the andragogy associated with using these tools

b) Lack of empirical evidence to substantiate their educational effectiveness

Visualisation is clearly advantageous in supporting recall and animated renderings have proven themselves. However, in order to reach beyond recall, it is necessary to engage the learner to construct their own meaning. This cursory review of the literature draws on research within mainstream workplace learning and 3rd level education. The studies in the field of algorithm visualization suggest systems highlighted the benefits of strongly scaffold interfaces, reduced extraneous cognitive load and testing facilities.

Andragogy and its relationship to workplace learning are relatively recent additions to academic study. Many branches of psychology, philosophy and andragogy itself provide fundamental insights into 'how' and 'why' adults learn. With so many different influences, the area becomes complex. Out of this complexity comes the need to engage in a manner characteristic to adult learning, provide a flexible learning environment, situate learning in an individually and socially relevant context and provide a toolkit from which the learner can construct their own meaning.

By considering interactive graphical animations as semiotic mediators, learning schema may be compiled to suit a work based learning environment. Animation based mediation can create a learning experience rich enough to support an intense knowledge building dialogue.

Subsequent chapters will describe how these learning's can be employed in the development of a simulation based tool kit built for the purpose of research into workplace learning.

This prompts the following research questions with regard to the specific context of workplace training;

**Question 1 (TEACHER AND ARTEFACT: SEMIOTIC MEDIATION): Does a graphical visualization tool mediate a rich learning experience for those training on work-related activities in a workplace environment?**

**Question 2 (LEARNER AND ARTEFACT: CONSTRUCTIVIST LEARNING): Is knowledge constructed by the adult learner interacting with the artefact as a SEMIOTIC MEDIATOR?**

**Question 3 (TEACHER AND LEARNER AND ARTEFACT: ENHANCED SOCRATIC MODE): In this workplace training environment, does the use of this artefact promote inquiry dialogue between the adult learner and the trainer?**

The learning platform as a research artefact and the research methodology was designed to attempt to answer these questions.

# Design

## Introduction

The outline review of the literature has shown graphical mediation of inquiry-based, constructivist learning to be an area of interest.

To examine some of the mechanisms and influences involved and to answer the research questions outlined in the literature survey, the research artefact has been designed as a learning platform for workplace training and it is the research questions, in line with issues and propositions raised in the literature, which informs the design of the learning platform.

This chapter covers the key design elements, a walk through of the system operation, justification of the use of this technology as a learning tool. It also describes the artefact produced once the research has been completed.

### Context

It is important to understand the context behind the research and the design of the artefact. The researcher holds a capability development role within the management structure of the featured organisation. The target audience are a group of workers based in a beverage production and packaging facility. They come from mixed educational backgrounds ranging from university education to apprentice training. Some have no formal training or educational background. All have received situated training in their workplace and have a specialised skill set and knowledge base to operate and maintain the equipment they use on a day-to-day basis.

There are however a number of gaps in their understanding of the operation, the detail of the equipment and the physics and mechanics upon which this is based. This has a negative impact on their ability to respond to unusual or infrequent occurrences and the training team at the facility constantly seek new and better ways to bridge these gaps within the limits of agreed work practice and limited resources.

Having consulted with the training team, two areas of interest were selected for the development of training modules to assist the workers in those areas build their detailed knowledge and close gaps in their understanding of how and why the plant and equipment operate in a particular way. The production equipment is highly automated and is operated via an advance Human Machine Interface (HMI) otherwise referred to as the Supervisory Control And Data Acquisition (SCADA) system, which is considered to be “best in class” for the beverage industry.

The beverage industry in Ireland is included in the broadly defined Fast Moving Consumer Goods (FMCG) sector, and the research is applicable to workers and workplace training beyond brewing and beverage application.

### Environment

There are certain environmental considerations, which must be noted. The facility is part of a much larger organisation. It has very specific training and development programs. People development and skills enhancement form a core part of the corporate organisations ethos. This is supported through extensive training programs and one-to-one coaching. However, commercial pressures mean both time and costs are important factors when deciding on the means by which to build skills and deliver training. The corporate organisation have made some small steps into the areas of Computer-based Training and Intranet-based Training Modules, and all of the participants in this research will have been exposed to that format.

There is currently a restructuring within the organisation worldwide and, while this will take time to complete, it has had an impact on this research, distracting from the training programs in which the research is set.

This restructuring will increase the need for better, more efficient means of skills development and knowledge building. New facilities proposed in the restructuring plans will require skilled and semi-skilled workers to operate in a more advanced, more exotic automated environment with fewer people and less time for problem solving.

# Design Specification

As noted in the review of the literature above, the emphasis of an effective learning environment must be on the concept being taught, not on learning how to use another tool. The artefact built for this research has been designed for intuitive operation with respect to the skills and experience of the target audience.

The artefact was developed using Adobe Flash and ran on widely available web browsers. Process & Instrumentation Diagrams, Functional Design Specifications and HMI screen shots were used to build up the graphics. An extensive period of consultation preceded the roll-out of the training program and the developers were in constant contact with representatives of the target audience. At the end of the design period, a ‘Train the Trainer’ session took place to demonstrate the functionality of the artefact and hand over the training manuals. This session incorporated a ‘challenge & build’ where the trainer group contributed to the overall research.

The key design principles from the literature and the researcher/practitioner experience were as follows (see below Appendix D: Design Table);

- Interactivity; must be highly interactive to engage the learner (Jarc, Grissom, Stasko/ Constructivists).
- Authentic activity; must be highly relevant to activity in the specific workplace context (Billet).
- Constructivist engagement; must be capable of generating unintended outcomes (Squires).
- Use of diagrams; must provide for use of diagrams to support ATS theory of recall (Anderson).
- Epistemic fidelity, must be sufficiently 'true-to-life' to support Rochelle's theory of recall (Rochelle).
- Teacher accompaniment, must specifically espouse the relationship between teacher and learner in a way that promotes dialogue. (Brown).

Fundamentally, the artefact was designed to ask more questions than it answered, prompting the learner to discover these things beyond the artefact, either with other learners or the teacher. Sufficient complexity was built in to push the learner in the direction of the teacher in search of answers. Conversely, sufficient functionality and epistemic fidelity was built in to allow the teacher to use the artefact to facilitate a learning dialogue with the learner.

# Initial Development Work

The initial approach to developing an artefact was to build a constructionist environment for building and simulating complex hydraulic systems. A constructionist learning approach looked like it would have the greatest learning potential. The first two research artefacts were designed around this principle. The tool kits were built for learners, in this case machine operators, to construct their own pump, valve, pipe and vessel systems. They would be given a task to meet certain processing requirements and build a system accordingly. The detailed design involved developing a suite of 'intelligent' animated valves. These diagrammatically represented a range of actual valve types in a manner familiar to the operators, and which would typically be encountered in the facility (see Figure 9 below). These valves could be 'dragged and dropped' onto a grid representing a network of pipes which in turn linked a collection of familiar vessels, pumps, and equipment. Once positioned on the grid, valves could be 'opened' or 'closed', pumps could be switched 'on' and equipment such as centrifuges, pasteurisers and fillers could be set to 'run'. By providing a 'test' button, the software could run an animation of the actual outcome produced by valve type and layout combination, highlighting gaps and weaknesses in the design. In this way the user would effectively test their own arrangements of pipes, valves, pumps and equipment in a safe environment.

The breakthrough learning for the operators lay in their ability to design and test layouts into which they otherwise had no input. Central to the activity of the operators creating complex networks was engagement in rich, exploratory dialogues with the teacher around the selections they made.

It is important to understand that basic functions could be achieved in several different ways but the valve selections would have further implications for the safe, clean and reliable operation of the whole system. This would create ample opportunity to discuss the benefits of choosing one valve type, combination or routing system over another. While there would be a clear distinction between 'good' and 'bad' design, there would be ample scope within those limits to create new and interesting ways of achieving the same result.

In terms of learning outcomes, this would have supported a fundamental understanding of these systems for the operators and would have had orthogonal benefits for health & safety and system design into the future. Operators would, for instance, have insight into the difference between a health & safety risk resulting from poor valve specification and one arising from poor network design.

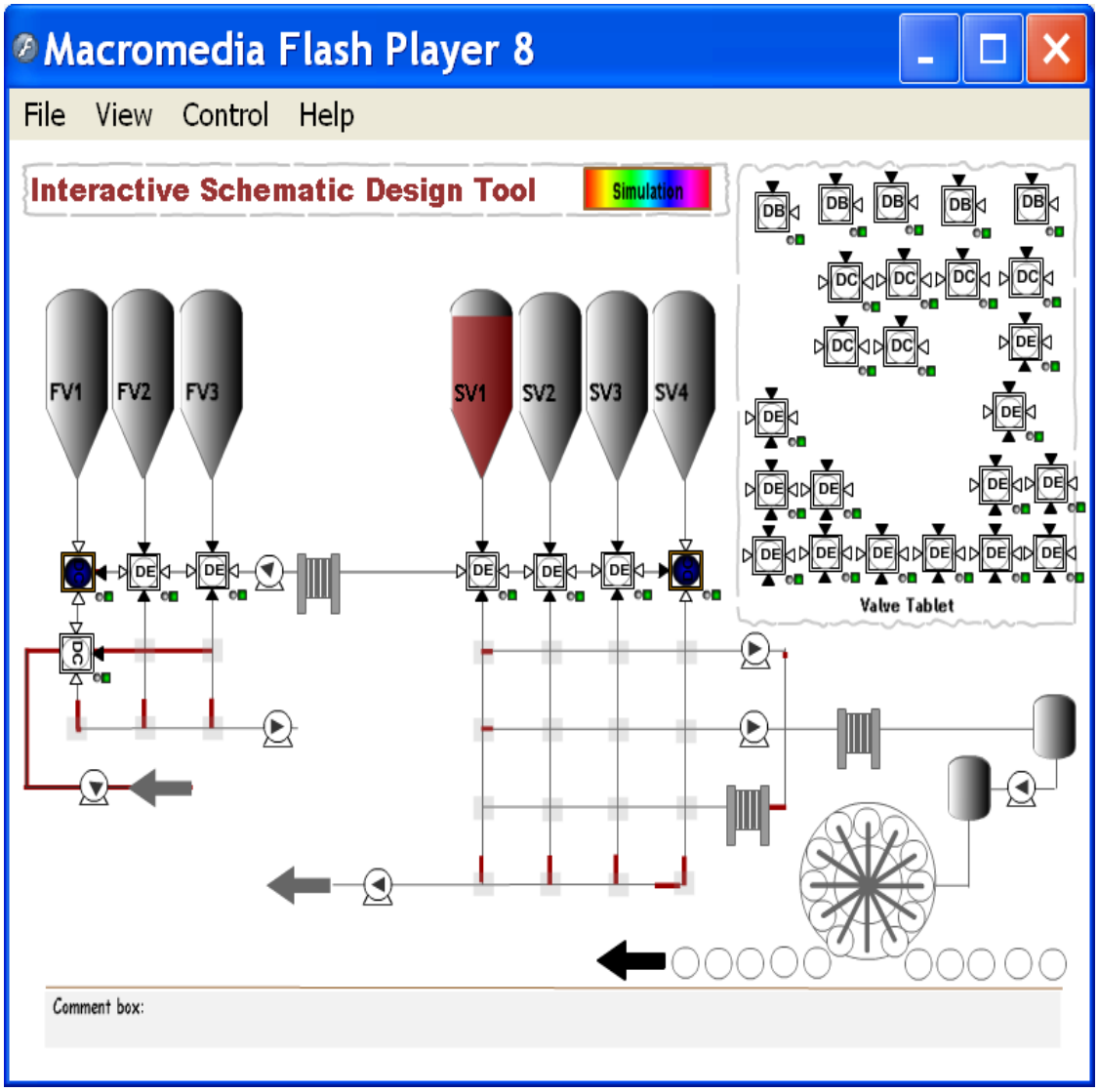


Figure 1 Early Constructionist Approach: Interactive Schematic Design Tool

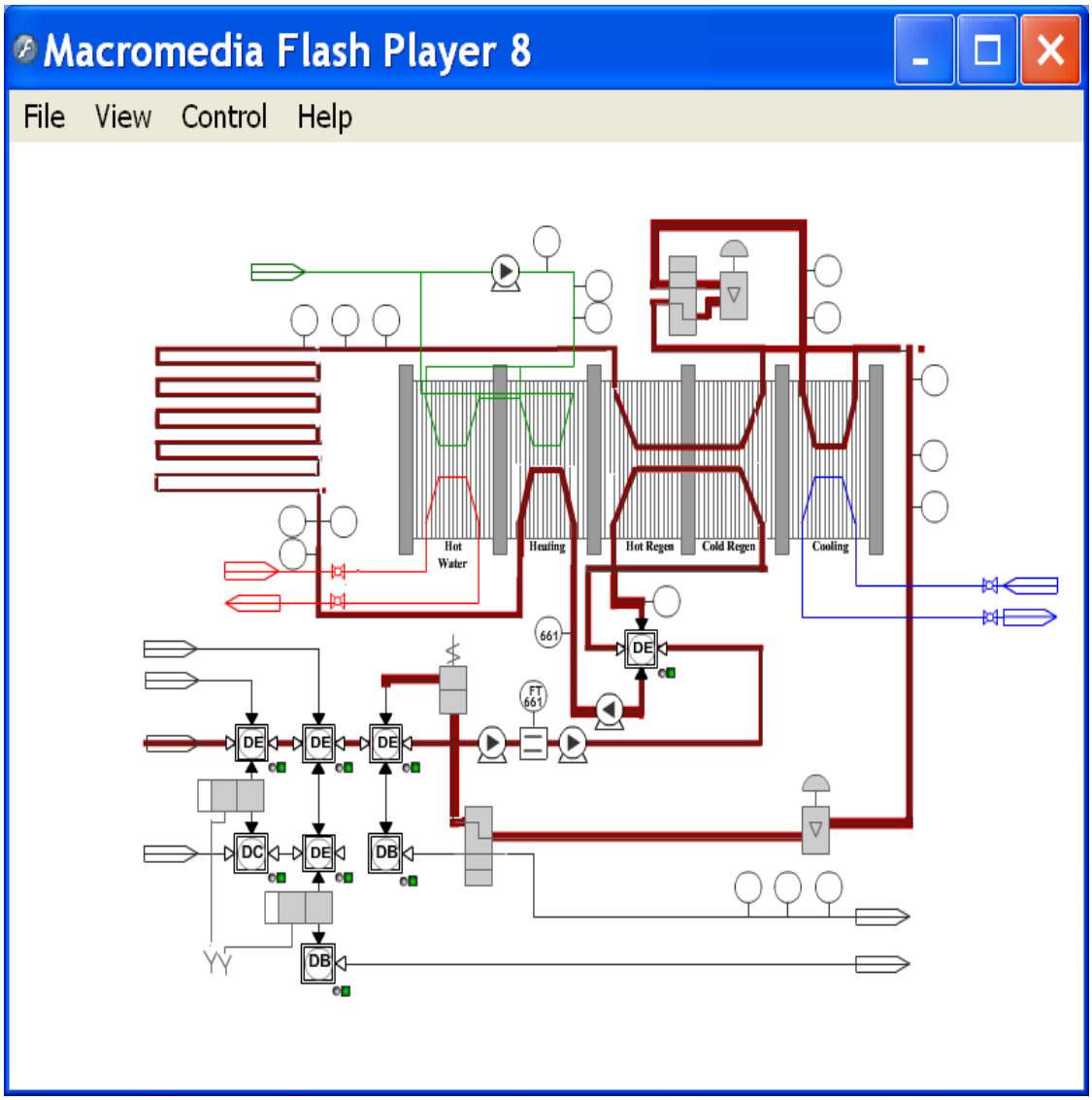


Figure 2: Early Constructionist Approach: Applied to Beer Pasteuriser

## Design Justification

However, problems arose during the development of this system. The learning outcomes were not sufficiently understood and this posed a problem for the training group. Without clear intent, it was not possible for the target audience to ground the training or the functionality of the artefact in the 'real world'. The characteristics of workplace learning described by Billet (see above) identify the need to have relevance and clarity of purpose. Specifically, Billet notes amongst his factors which limit workplace learning those "Instructional media, as knowledge format disembodied from the activity". Applying that rationale in this application, because the operators are not normally engaged in 'drag and drop' design, and consequently do not relate to their working environment with that level of flexibility, it would limit the extent of their learning by providing them with such a tool. After much debate with the local trainers and area managers, it was agreed to park the 'constructionist' artefact in favour of developing a more 'constructivist' learning tool.

# Final Design

The final design was arrived at through consultation and consideration for the design specification above and the needs of the learners. The new experimental training artefacts were given the term Interactive Animated Training Modules (IAT Modules) and alternative subject matter was identified by the training group as representing a knowledge gap. Previous attempts to fill this gap through conventional means had a relatively poor rate of engagement and 'blind spots' in the knowledge and understanding of these operations persisted. This made the material and the means of delivery ideal for research.

Furthermore, (touching on Maslow's consideration of the adult learner) it was necessary to address the issue of 'delighting the learner'. Early feedback on the 'robustness' of the artefact indicated a strong preference to build the finished article to a high standard. In short, there was little tolerance within the target audience for poor operation or functional failure of the artefact. This also speaks to the notion of keeping extraneous cognitive load to a minimum. Any issue with computers freezing up as a result of bad code or animations failing to run would be considered a critical failure of the overall project. In light of this, the training manager insisted on the new IAT Modules being built to a commercial and professional standard, and so an outside specialist was retained to develop a new artefact to the required specification. A suite of 'mock-ups' was built using Microsoft Powerpoint for the graphics and Microsoft Exel for the mathematics. These were used to build the design for the new interactive animations from which the specialist could build the learning artefact in a robust and polished fashion. These design tools were included in the handover package to the training group for future use in adding to and amending the final IAT Modules.

# Operation of the Artefact ('Walkthrough')

The artefact focused on two machine operations; the first was a yeast thickening system using cross flow filtration, the second was a beer pasteurizer. The animation was developed to reflect an actual computer screen shots used by the operators to run the automatic programs for the machines. This is the view normally seen by the operators. The diagrams represent valves, pumps, pipes, tanks, vessels and sundry other pieces of machinery in a way easily recognizable by the target audience. These components combine together to carry out the particular treatment or function required by the operators in their normal day to day duties. Exact timing, activations and status monitoring are all fully automated through a network of high specification Programmable Logic Controllers or PLC's. As the operators have not been involved in the design and commissioning of these systems, significant gaps in understanding exist. These gaps do not affect their day to day duties but can impact how they respond to and report abnormal operation. These gaps also limit their ability to improve the process performance or product quality.

The normal operation of the machine takes a number of process steps. These were reflected in the animation which was set out in the same sequence using the same naming titles and conventions. Care was taken with the layout to avoid over complicating the image as animation would not normally be part of the HMI graphics. Thus, elements which were not relevant to the learning outcome were omitted.

## Training Module 1: Cross Flow Filtration 'Pall Sep'

Step 5 (Figure 2 below) represents both complexity and interaction. In this step the user has a range of parameters which they can change. Some of these user parameters reflect user parameters from the HMI. The rest are parameters made available to the user to model certain conditions which may arise during the normal operation of the machine. For example, the parameter YEAST_A is used to model the effects of a blockage in filter A caused by a build up of thickened yeast in the flow paths. PROT_A on the other hand models the impact of protein build-up on Filter A filter membrane. The impact of changing these values is seen in the pressures and flow rates across the system. They are also reflected in the composite values which are copied from the HMI.

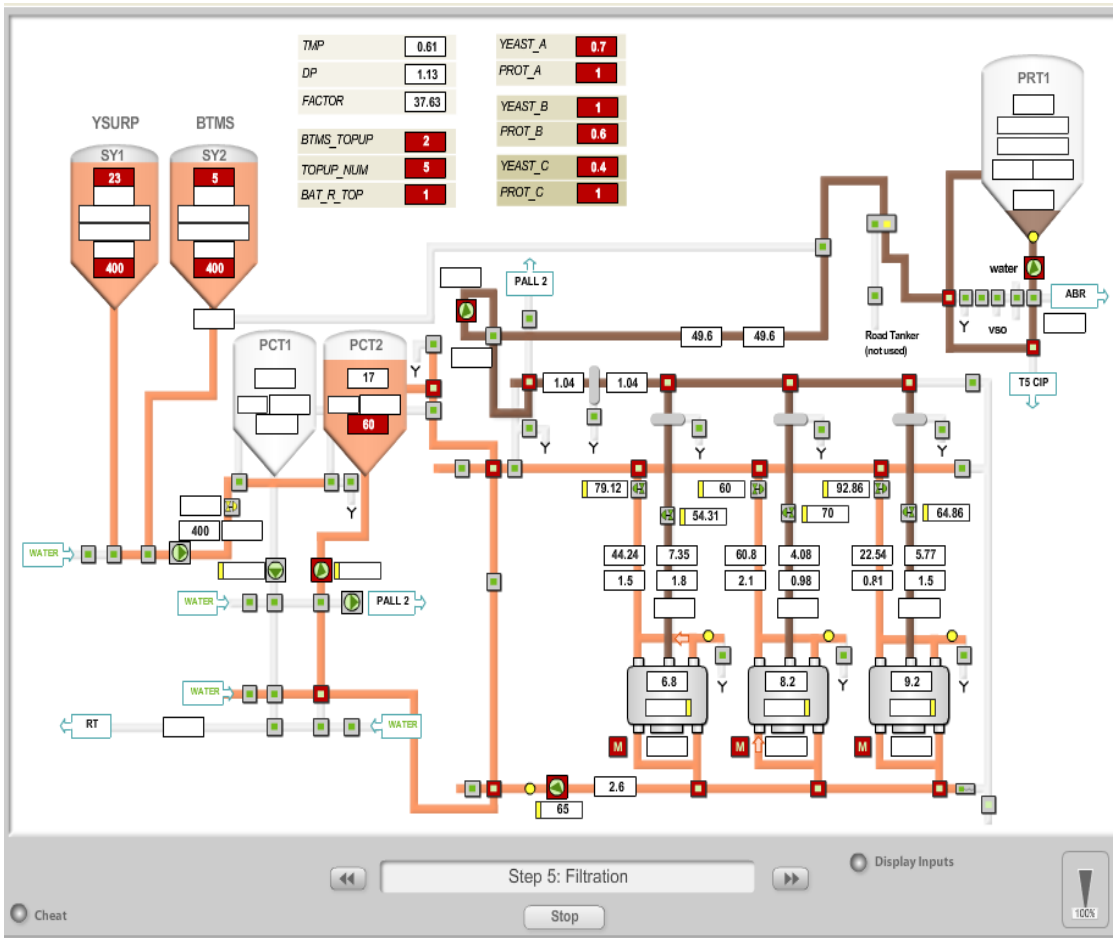


Figure 3: Pall Sep Step 5: Filtration (input fields are highlighted in red).

Step 5 represents the most challenging and the most interactive of the animation elements. It is in this area learners can construct their own meaning by manipulating the variables to create new outcomes. However, this is in the context of simple numerical simulation and does not represent mechanics of fluids or hydraulic modelling. This is a training tool for operators and not a hydraulic simulation tool for design or fault finding. The numerical model broadly represents the observed characteristics of the machine and in as far as the numbers are indicative of the correlation between certain physical parameters, they are true.

It is also in this area unintended uses may occur. How or why certain values may be manipulated is not prescribed to the user. Once the user has done with the interactivity in step 5, they can step on through the remaining sequence steps. The intellectual challenge softens and the learner is back on familiar ground of looking at routes and automated functions.

## Training Module 2: Beer Pasteuriser 'Keg Plant'

Training Module 2 (Figure 4 below) is constructivist in its approach. Input fields are provided which allow the learner to explore the impact of changing parameters on the overall balance of flows, pressures and temperatures. The animation uses temperature, pressure and flow 'modes' to achieve this. Each mode in turn allows the user to manipulate one physical characteristic and see the impact on the other two.

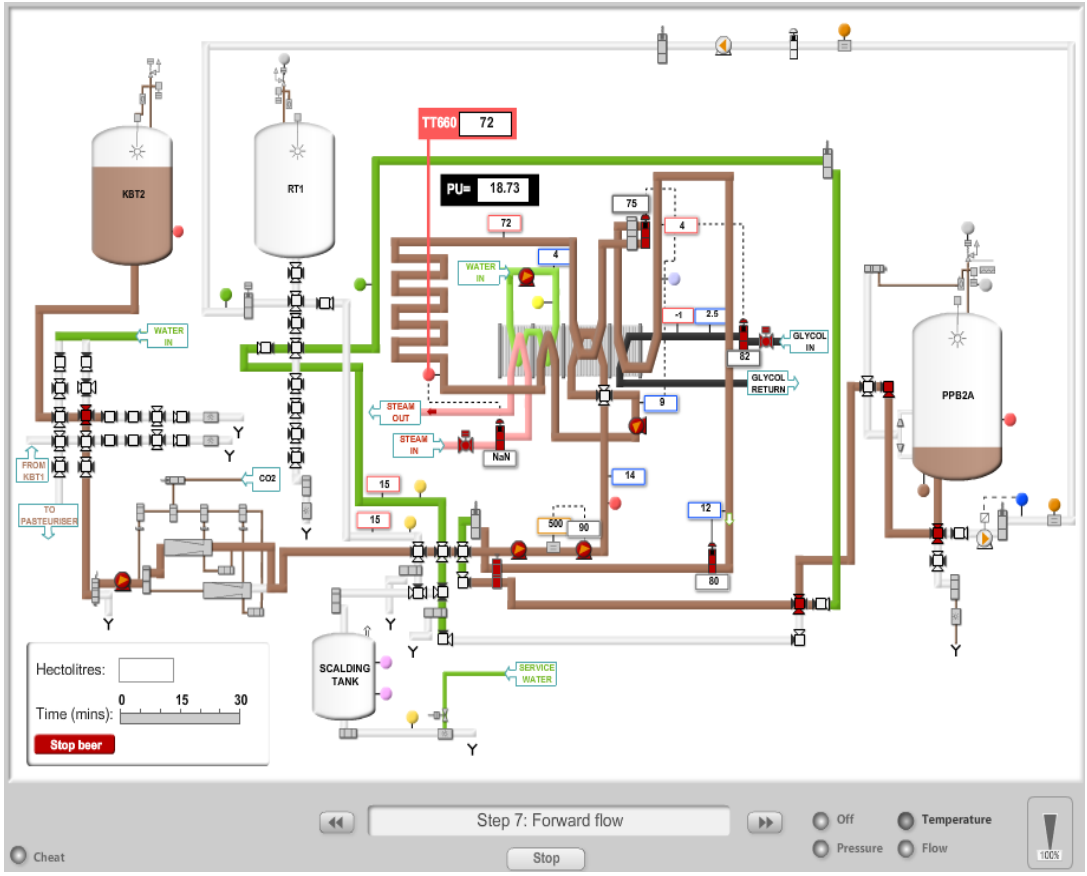


Figure 4: Pasteuriser Step 7: Forward Flow – Flow Mode

# Exercise Design and Dialogue

Once the learner has run through each of the steps and is familiar and comfortable with the operation of the animation, they are provided with three exercises by the teacher. They are encouraged to work together in pairs and to ask questions of or discuss these with the teacher. They are encouraged to go back through the animation and use it to compile answers to the questions posed in the exercises. The questions look for the learners to interpret what they see in the animation and make general observations. At the end of the allotted time, the learners are invited to present and discuss their findings.

To ensure these rich dialogues evolve, a lesson plan is provided. This is designed and agreed in conjunction with the technical training group. The output is a comprehensive training pack for the trainers (ref 'Trainer Training Pack KRP Pasteuriser' and 'Trainer Training Pack Pall Sep' in the attachments.) These, along with a clearly defined intent in the form of Training 'Purpose, Outcome, Structure & Timing' (or POST) prepare the trainer to elicit enquiry dialogue and encourage hypothesis' from the learners.

Example of Training POST for the Pall Sep Lesson

| E1: Animated Training Module 2: Learning POST Pall Sep<br><br>This is designed for 4 to 8 learners with one teacher running the session. |
|---|
| **Purpose** |
| To teach Process Brewers the Pall Sep 'top-up system'. The Brewers are assumed to know already the basic operation and steps of the Pall Sep system. This lesson is to address gaps in that knowledge, including;<br>o One shot from YSURP<br>o I box selection; 1 shot YSURP only or NO SEL in I box.<br>o impact of DP<br>o impact of TMP<br>o impact of 'FACTOR'<br>o Pump Speed > 98% |
| **Outcomes** |
| o approximately predict the running time of the Pall<br>o improve I box selection |
| **Structure** |

Initial step-by-step run through of the animation. The teacher talks through what's happening and how to use the various features of the artefact.

While in the filtration step, the teacher demonstrates how to change various pressure and flow parameters. At this point the teacher is preparing the learners to be able to carry out some basic exercises on their own.

The learner is given a worksheet and asked to investigate three scenarios,

- Investigate the various parameters, which will cause a flush, specifically DP, TMP and FACTOR. Learners should make a note of what each factor and how it works.
- Investigate the use of the I-box parameters and compile some scenarios which would require changing them.
- Run the supply pump at different speeds and see how the effect on flow and pressure at certain points on the plant.

Having allowed the learners (preferably working together in pairs) to work through these scenarios for around 20 minutes and making notes of their observations, the teacher brings them back together as a group to discuss and capture the key learning's for about 10 minutes. The important aspect of this part is to generate good discussion and debate as to how and why certain things happen. The learners now progress to the question sheet. This contains 20 multi choice questions. The learners are free to move back and forth between the quiz, their notes and the animation. The learner must go through the quiz sequentially and cannot check their score until they get to the end. However, they can repeat the quiz as often as they wish and should be encouraged to do so by the teacher until they have correctly answered and understood all the questions.

**Timing**

Total = 90 minutes

- Introduction; teacher explains how the lesson is intended to run **= 10 minutes**
- Presentation and Demonstration; teacher takes class through animation step-by-step and demonstrates use of interactive elements **= 20 minutes**
- Investigation and Interaction; learners split into pairs and work through the prompts to work out how the parameters inter-relate **= 30 minutes**
- Discussion The class present their findings and the teacher highlights any missings **= 20 minutes**
- Quiz the learners take a test to check understanding of specific outcomes **= 10 minutes**

# Methodology

## Research Design

Yin (2003) posits that case studies are appropriate when the researcher has little control over events, the focus is on a contemporary setting and real life phenomenon are being treated, as applies in this instance.

The following is an opportunistic case study carried out to answer specific research question as highlighted by the literature review and posed by the brewing organisation with regard to developing new approaches to training. These questions are as follows;

Q1: Does a graphical visualization tool mediate a rich learning experience?
Q2: Is knowledge constructed by the learner interacting with the artefact?
Q3: Does the lesson promote inquiry dialogue over didactic teaching?

The design of the artefact, the resulting product and the subsequent interviews are intended to help answer these questions.

The research method was chosen based on the availability of participants and the relationship to the researcher. It was also based on the researchers' prior knowledge and expertise. This provided understanding of the threats and opportunities in attempting to introduce new ways of learning to an existing, well established group.

Questions arise on the affordances of the artefact and user preferences. However, the key question is the impetus to change from existing ways of learning and whether a previously untapped means of learning would be identified by the participants.

## Ethics

The criteria for the American Anthropological Association (Glesene & Peshkin, 1992) reflect appropriate ethical standards for qualitative research and data collection. Elements appropriate to this case study have been applied here. The participants were informed of the background to and purpose of the research. They were provided with the authors contact details and were made aware they could, on request, preview the dissertation. In the report, the anonymity of the participants is preserved.

## Data Sets

The research is based around the following data sets;

1. Video recording; trial learning sessions took place where the lesson was rolled out as per design. The trainers, having been trained, now rolled out the training to the target audience. These sessions were video recorded and the results were classified, coded and grouped.
2. Exercises sheets; participants were provided with exercise sheets. For simplicity, there were paper based and the answers had to be written into the spaces provided. They were used to indicate how

successful the participants have picked up specified learning outcomes. The multi-choice quiz also shows how many times the learners repeat the quiz, which is the used in triangulation with other data sets.

3. Course Evaluation sheets; standard training course evaluation sheets were also passed out amongst the participants to benchmark the trail session against a standard learning experience within the organisation. This incorporated a standard scoring format.
4. Feedback forms; forms were provided to give the learner an opportunity to feedback against selected areas of enquiry on the part of the researcher. The form includes an unstructured question to allow for unpredicted or unintended feedback.
5. Interviews; selected interviews were carried out with structured and semi-structured questions. This is a key data set and forms the core of the triangulation process. The questions are informed by the video record of selected classroom sessions, quiz results and feedback forms.
6. Practitioner/Researcher Notes & Observations; As a legitimate practitioner within the community, it is important to consider the researchers notes and observations as a valid data set. An observation protocol is defined for the specific application.

# Researcher Bias

As a practitioner researcher it is important to understand researcher bias in the work. This applies to the preparation of the artefact and its presentation to the research participants.

Participants may dilute their involvement because of their professional relationship to the researcher. The research may be seen purely in the interest of the researcher and not the learning outcomes of the individual participants. Alternatively, the relationship between researcher and individual participant may give rise to positive or negative responses or influence the overall performance of the participants.

The desire on the part of the researcher for the work to succeed may also prompt positive outcomes to be projected on the data collection and analysis. This effect may be magnified by the nature of the research i.e. building a learning artefact which may ‘work’ or ‘fail’. In this instance little interest or uptake with the animation would represent ‘failure’. Where the results are ambiguous, a researcher could actively seek positive trends. To combat this effect the researcher to be mindful of such tendency. In addition, the local training manager reviewed the veracity of the research data to ensure the outcome and recommendations were robust.

# Data Collection

## Sample Set

The site and group were selected because they were representative of a situation where workplace learning is carried out. The bulk of learning is experienced based and consists of on-the-job training and learning. Some material is consigned to record but the learning process is essentially by doing. There is a strong cultural and community identity. There is also a precedent and acceptance of change with technology at its centre. In summary, here is a community of practice familiar and comfortable with looking

to technology for solution to practical problems. As a consequence, they are also inundated with proposed technological tools and are discerning of using technology for its own sake.
The site was a good example of mid-range manufacturing environment.
Characteristics common across the industry would be;

- computer literacy
- technology infrastructure with suitable ubiquity and access
- computerized core business systems
- email, internet and other web-based formats
- exposure to limited CBT (Computer Based Training)

The participants were selected on the basis of;

- availability
- need for understanding of the material
- prior attempts to understand this material
- opportunity to provide a sufficiently rich learning experience

## Quiz results and Feedback Forms

For simplicity, these were paper based, hand written forms. The results were transcribed back into a spreadsheet for processing and analysis.

## Sampling

When examining the data returned by the research, a purposeful approach was used to selecting candidates for interview. The interviewees were chosen based on background, role and influence within the organisation.

## Observational Role and Process of Observation

Observations were made on the reaction to the initial roll out all the way through to the body language during the interviews. These were recorded in a research notebook and subsequently transcribed into a table of observations. The protocol of observation was a filed notebook with time/date entry, observation reference, subject, observation details and reflections. In general, observations were asymmetric and reflective in nature.

## Interview

The interviews were the primary source of research data. Semi-structured research questions were developed with one open question at the end to allow for wrap-up. These questions were compiled to specifically address the research questions at the heart of the project and were identified by immersion in the data from the trial. They were intended to probe and develop underlying reasons behind the themes emerging from the other data sets. Finally, participants were invited to offer any comments on the overall project or anything, which they may feel relevant to the research subject or process.

## Interview Protocol

A protocol was developed to ensure a consistent, courteous and ethical interview process. This included a short recap of the research, assurance of anonymity, timing and permission to use a recording device. A page containing the interview questions was prepared which had a protocol checklist in the header. This also contained logistical details such as participants name, time and date and any details particular to the interview.

## Qualitative Data Analysis Process

Cresswell offers the following process for data analysis;

- Collection; compile digital field data, audio & video recordings, field notes.
- Preparation; transcription into common format, in this case spreadsheet format.
- Review; read through data set from start to finish.
- Codification; application of codes to the material to identify areas of commonality.

This is an iterative process as codified data can prompt further data extraction from the field such as supplementary interviews or questionnaires.

Data was organized in an MS Exel workbook. Data was categorised as Multi-choice Inputs, Feedback Questionnaires, Participant Interviews, Teacher Interviews, Expert and 3$^{rd}$ Party Interviews, Video Recording and Researcher Observations/Reflections. Tables were set out to allow for ease of coding and sorting using Exel's data sort and filter.

A coding table was developed in the spreadsheet. Here the codes were cross-referenced with instances across the various data types and facilitated the emergence of norms and trends. Codes were reviewed for similarity and overlap. A set of overarching themes were determined. From these we can begin to answer the research questions.

# Findings

## Introduction

The purpose of this study was to investigate the triangular relationship between adult learner, teacher and computer- mediated graphical learning tools in a workplace environment. The research was carried out with a group of participant workers in the training facility of the automated beverage plant in which they work. The training session was delivered by a local trainer in conjunction with the author (who is also a member of the local technical training group), using an animated interactive training module which was the research artefact developed specifically for the trial.

The three research questions addressed were as follows.

**Question 1 (TEACHER AND ARTEFACT: SEMIOTIC MEDIATION): Can a graphical visualization tool mediate a rich learning experience for those training on work-related activities in a workplace environment?**

**Question 2 (LEARNER AND ARTEFACT: CONSTRUCTIVIST LEARNING): Can knowledge be constructed by the adult learner interacting with the artefact as a SEMIOTIC MEDIATOR?**

**Question 3 (TEACHER AND LEARNER AND ARTEFACT: ENHANCED SOCRATIC MODE): In a workplace training environment, can the use of this artefact promote inquiry dialogue between the adult learner and the trainer?**

The data was systematically gathered and processed. The treated data was reviewed for evidence which could answer these questions. Unexpected outcomes were also noted and considered.

### Community Profile

There were 18 participants in the research. These ranged in age and experience. All had some prior knowledge of the material covered ranging from novice to expert and many had attended formal classroom-style training sessions on the exact content of the material in this trial session. The results of previous training sessions were mixed, with attendants struggling to conceptualise the complex aspects of the process. This was confirmed by one of the organisations technical trainers in interview (ref Appendix D5: Interview Transcripts Section DD3) “With the lecture style, it either sinks in or it doesn’t.”

The participants can be categorised into a number of sub-groups. Five are masters in their field and they typically had conceptual difficulties with the integration of certain key components into the whole process. Nine are intermediate practitioners who have specialist knowledge in particular components

and a low level understanding of the whole process and four are relatively new to area, having had some recent on-the-job training and experience using the system. Across the group there was a range of familiarity with the subject matter. All the participants stood to benefit from a deeper understanding of the material.

All participants were computer literate in areas such as email, MS Outlook, shared files and data storage and retrieval applications and all were comfortable with accessing and using web based applications. All had easy access to PC's and network access to the web. None of the participants had previously used animated training applications in a formal sense. All had previous experience of Computed Based Training Modules (CBTM's) in the form of self-assessed training modules for low level subject matter such as training in the use of computerised maintenance management systems, corporate policy familiarisation modules, standards appreciation modules, soft-skill development such as time management, decision making, etc... and sundry compliance training such as automated travel & expense claims systems training. These typically are web-based delivered over the global organisations intranet to local workstations.

The trial was 90 minutes long, organised by the local training manager as part of the routine training arranged for employees at the plant. This truncated trial session yielded good observational material and provided the experience from which participant interviews could be carried out. However, regardless of the richness of the experience for the participants, its brevity detracts from the robustness of the findings.

The local trainer who participated in the training took the lead on the first leg of the training session using the artefact in conjunction with other training material to deliver a quick recap, description and demonstration of the workings of the Pall Sep unit using the animation as a demonstration only. The second leg of the training session was the interactive element, co-ordinated by the author as well as the third leg which was a general discussion about the format and the content of the training session. The second and third sessions ran into each other and lasted 70 minutes in total.

## Coding & Themes

Coding was initiated by analysing the interview transcripts and subsequently extended by examining the video recordings. A micro analysis of words and phrases was applied to elicit codes from the data. Codes were identified, ranging from structural comments about the look and feel of the artefact to requests for corrections or more detail in the material provided. These were rationalized into code clusters of related codes and from these themes emerged. These are listed in the table below.

| Theme | Description | No. of combined code references |
|---|---|---|
| Theme 1: | Constructed meaning | 65 |
| Theme 2: | Mediated Learning | 62 |
| Theme 3: | Learning Dialogue | 46 |
| Theme 4: | Functionality | 40 |

Table 5-2: Themed Findings vs. Number of Code References.

### Findings Layout

The findings are detailed under each of the three research questions below. Under each question, the observations and data relevant to it are discussed with references to and quotes from the data sets. These come primarily from the video clips and the interview notes but also the Trial Feedback and Course Evaluation forms. Where the video footage is referenced, the particular clip is noted i.e. 'Demonstration', 'Interaction' or 'Discussion', and the time stamp for the event referred to in the clip appears as a suffix e.g. 'Interaction 21:10' refers to the video clip 'Interaction' at timestamp 21 minutes and 10 seconds on that clip.

# Semiotic Mediation

**Question 1 (TEACHER AND ARTEFACT: SEMIOTIC MEDIATION): Can a graphical visualization tool mediate a rich learning experience for those training on work-related activities in a workplace environment?**

This question is aimed at understanding what role the artefact would play as a Semiotic Mediator to heighten understanding amongst workplace learners and create breakthrough learning moments. The evidence from the data identifies the artefact 'being included in the process [of learning].....the tool alters the entire flow and structure of mental function' (Vygotsky, L. S. 1962), suggesting that graphical visualisation worked very well as a semiotic mediator during the course of the trial.

### Semitic Mediation provides clarity

The participants were observed using the artefact as a means to communicate amongst themselves and with the teacher. There are numerous references to 'clarity' within the data sets, in the context of the artefact bringing clarity to the subject matter. This is interpreted as indication of the artefact being used as an effective semiotic mediator. Interview feedback points to the clarity the artefact brought to an already familiar but none the less complex process and how this facilitated the exchange of ideas. One participant commented at interview. *"The whole thing was excellent. It worked really well. I've used that system for years and I've never seen it with that level of clarity"* (ref Appendix D5: Interview Transcripts Section EE1).

In the context of epistemic fidelity, the participants did not revert to sketching or drawing but instead continued to use the graphical model right through the session. At Interaction 25.50, participants are still using the animation for pointing and mediating conversations. This correlates well with the Trial Feedback forms on the question of 'How did you rate the demonstration aspect of the animation?' Scores were all 4's and 5's with an average score of 4.33.Comments were consistent; good, very good and excellent being the most common terms used under this category. One participant commented on the form *'excellent. A very clear representation of a complex process'*. This is an achievement indeed coming form an audience all of whom have prior knowledge of the plant and process.

## Peer discussions through Semiotic Mediation of the artefact

The peer to peer discussions arise again and again in the video footage. The code table notes 28 references to peer to peer discussion. It further notes 20 references to using the animation for peer to peer teaching. For each and every instance, the participants gesture and point to the screen, trialling various values to check for uncertain outcomes, manipulating the player controls, testing their preconceptions with respect to the operation of specific valve combinations and integration, clearly using the artefact as a mediator for the discussion. This aspect is further developed as part of Question 3 below under the section on Learning Dialogue.

## Expert analysis through Semiotic Mediation of the artefact

At *'Interaction 25:29'* two functional experts engage in a detailed debate about the correct function of the process. This is of interest for two reasons; firstly, at this point the participants have been reviewing and discussing the material for 25 minutes. To see a continued high level of interest and enthusiasm from functional experts amongst themselves suggests the animation has prompted a deeper level of discussion amongst them than they could have achieved without the graphical mediator. Secondly, these two are functional experts on the same team, working closely together using this equipment day to day, studying this process and struggling with it when it presents problems. They completed the exercises quickly and continued to use the animation to delve further into the aspects of the operation which were unclear or for which they each had different ideas of how it worked. In this instance, one had a more complete understanding than the other. They used the animation and the opportunity to bring their understanding up to a level and then develop it further together. One of these two participants noted at interview afterwards. *"I know what the Pall does, as opposed to HOW it does it. This was perfect for visualisation. Seeing it animated was very powerful. ....seeing movement was really useful. Hearing someone talk about it is not enough, which makes the animation very useful"* (ref Appendix D5: Interview Transcripts Section AA1).

The design process highlighted, the importance of Epistemic Fidelity (Rochelle, 1994) and the application of diagrams for ATS recall (Anderson, 1978) as key to the effectiveness of the artefact. It further highlighted the need for authentic activities for workplace learners (Billet, 2001). By ensuring a high quality rendering of the 'live' plant , as close as possible to the look and feel of actual control system interface and by engaging with the technical training group to select relevant subject material, the artefact emerged as an effective Semiotic Mediator.

In summary, the workplace environment produced both the correct context and abundantly rich content for the development of an effective Semiotic Mediation tool in the form of a graphical animation. This was evidenced by the clarity it brought about the process to the participants, the peer dialogues it facilitated, the emergence of a zone of proximal development during the trial session and the analysis of experts building new levels understanding amongst themselves using the artefact.

# Constructivist Learning

**Question 2 (LEARNER AND ARTEFACT: CONSTRUCTIVIST LEARNING): Can knowledge be constructed by the adult learner interacting with the artefact as a SEMIOTIC MEDIATOR?**
Central to constructivist learning is the ability to interact with learning material so as to construct meaning. This question is aimed at understanding what role the artefact such would play in helping to develop constructivist learning moments for workplace training. It looks to see if participants use the interactivity to generate new outcomes and if, in doing so, will construct new meanings for themselves to build on their existing store of knowledge.

## Higher Order Thinking

The evidence from the data indicates the interactive element of the artefact was capable of generating unforeseen outcomes in the process simulation and thus constructed new meaning (constructed knowledge) for the participants.
This can be best summed up by one of the quotes from the interviews; *"The interaction was brilliant..... They (Operations Workers) don't really understand what happens (in the process)... which is really complicated. When people started using the interaction (started to use the interactive element of the animation) and changing the values, you could hear the sound of pennies dropping all round the room"* (ref Appendix D5: Interview Transcripts Section CC2). This observation is indicative of how the interactivity of the artefact established a means for participants to construct their own meaning, leading to the sound of "pennies dropping all round the room". In the Trial Feedback Forms the question of 'How did you rate the interaction aspect of the animation?" scored 4'sand 5's on a scale of 1 to 5, with an average of 4.3. Here the comments similarly were *'very good' and 'excellent'*. The comments included *'I feel it adds to a better understanding'* to *'lets people work out and understand process themselves'*. This supports Grissom's work where he concludes that as the level of learner engagement with the simulation increased, so did the understanding. In order to decide whether the participants tapped into their higher order thinking skills, it is important to assign a ranking to the observations from Blooms taxonomy. The video observations and interview feedback indicate the participants were employing a level of analysis which corresponds to Blooms level 4 and sits within the range of Higher Order Thinking Skills.

## Immersion

In the trial feedback forms (ref; Appendix D2: Trial Feedback Forms) the interactive aspect of the artefact scored well, 4.3 out of a possible 5. In the training evaluation forms (ref; Appendix D3: Training Evaluation Forms), the feedback was unambiguous with *"clear and enjoyable"* written in the comment box on three different forms. This supports the observations of enthusiasm from the video and the comments from the interviews. One such interviewee comments *"Sometimes when you're bombarded with words and talk you can't really see the wood from the trees. It's really good to be able to play with the system yourself. You can't do that on the live system. It just makes it a better experience; to be able to immerse yourself in the material"* (ref AppendixD5: Interview Transcripts; Section AA3). This process of 'immersion' as described here, provides the ideal condition for the processes of accommodation and assimilation as described by Piaget (Piaget, J. 1952)

## Play

The role of 'play' is important here in the context of constructivist learning. The data shows clear evidence of this occurring amongst participants. What was observed in the video footage and confirmed in the interview transcripts was not casual play but the interaction of adults with engaging material, with a sense of freedom from normal restriction. Participants were free to play with processing conditions and parameters in a way that would be impossible on the actual 'live' plant. They were also free of the social restriction of 'making a mistake'. This is supported in interview (ref Appendix D5: Interview Transcripts Section CC3) *"It brings people in a cushioned way. It helps with the embarrassment. Some lads would be a bit embarrassed with lots of years working in the area. They wouldn't ask questions. But this brings them in and they get interested and get involved. It gets the interaction going"*. This is evidence of a 'wow' factor. The delights of learning outweigh the anxiety of making a mistake because the environment is safe. This brings the learning experience into the arena of social constructivism by developing the social meaning of important symbol sets and learning how to use them from more knowledgeable others.

## Characteristics of Adult learning

This constructivist learning experience does not exist in a vacuum and the interesting addenda from this point is the factors influencing adult learning are evident here in parallel with the characteristics of constructivist learning. The delights of learning are fed by the adult need for problem centered learning orientation (as distinct from subject-centered orientation) and suitable problems are easily found in the workplace. By finding a tailored fit with the requirements of adult learning, the learners proceed to engage fully with the interactive element and complete the learning process by constructing their own meaning.

## Prior knowledge

This principle of constructivist principles and adult learning characteristics being reflected in the same data is an interesting outcome. Another participant makes supporting remarks during interview. *"In normal circumstances, this type of material just goes over people's heads. It's OK to get involved in training if you already know a lot of what's going on, but for most people who are not so familiar, it's hard to get involved"* (ref Appendix D5: Interview Transcripts Section BB3). This comment supports the constructivist view that learners actively construct new information with reference to what is already known (ref Glaserfield above). It highlights the difficulty for novice learners of using the artefact and recognises the way the learning event suited a group of experienced and expert learners.

## Challenging assumptions

The same participant also notes *"People make assumptions about what they know. It was really hard and going back and testing and re-testing yourself made you challenges your assumptions about what you know"* (ref Appendix D5: Interview Transcripts Section BB2). This comment further highlights how the participants built on experience in a constructivist style. It also supports Brezis &

Cohen's work (see above) on instant feedback being a valuable feature of simulation-based teaching tool.

The design aspects contributing to the success of the artefact as a constructivist learning tool was the emphasis on a highly interactive environment by providing multiple input fields, navigation controls buttons and user friendly aspects such as zoom and pan. This high level of interactivity as an essential part of the design of the artefact is in keeping with research findings from Jarc, Grissom, Stasko and the Constructivists' School. To be truly constructivist, the interaction must be capable of providing unintended outcomes and this was achieved in the simulation where mathematical models were able to demonstrate the outcomes from improbable or unrealistic process inputs in terms of temperature, pressure and flow. The need to generate unintended outcomes is in keeping with the work of Squires on how designers of simulation-based teaching tools must weave into their design the opportunity for the learner to subvert the intended design and so learn in untended and opportunistic ways.

To sum up, the analysis of the data shows evidence of HOTS, Immersion, 'play', characteristics of adult learning, prior knowledge and challenging assumptions. In combination, these emergent themes indicate a rich constructivist learning experience with the artefact playing a pivotal role in the context of workplace learning. The basis for design including the work of Jarc, Grissom, Stasko and Squires was supported by the outcome.

# Enhanced Socratic Mode

**Question 3 (TEACHER AND LEARNER AND ARTEFACT: ENHANCED SOCRATIC MODE): In a workplace training environment, can the use of this artefact promote inquiry dialogue between the adult learner and the trainer?**

This question is aimed at understanding what role the artefact would play in helping to promote a dialogue between the learner and the trainer. It is specifically interested to see if an Enhanced Socratic Mode of dialogue evolves as a result of the use of the artefact.

With respect to the research question, the evidence from the data comes out positively insofar as the artefact did indeed appear to promote inquiry dialogue. It suggests the 'wow' factor generated by the artefact, created breakthrough opportunities where intense dialogues occurred leading to an Enhanced Socratic Mode of learning for the participants among themselves and with the trainers.

## Learning Dialogue

The participants employed their observations and the outcomes of their interaction to initiate dialogue and debate amongst themselves and with the teacher. Interviews and feedback comments noted how the artefact provided a confidence and a pathway for participants to raise issues they would otherwise have left unquestioned. This was supported at interview. *"AA and myself had a good chat about it and we talked about it afterwards too. There was a good bit of confusion about how it should work and that got us thinking and talking about it. ND was actually very good when we talked to him.*

*I know XX got confused about the pressures at the end but thats what its all about isn't it. Asking questions I mean. Its a great way of getting stuck into something like the Pall Sep"* (ref Appendix D5: Interview Transcripts Section EE3).

## Dynamic group reconfiguration

Dynamic group reconfiguration can be observed in the video footage. At *'Interaction 10:37* and '*Interaction 13:03'* interaction across the pairs of participants can be observed. This is significant for the participants. In a static group configuration, one expert can dominate the learning experience. In a dynamic situation, the participants benefit from a broader range of experienced others taking the lead in the dialogue. This is a feature of Enhanced Socratic Mode teaching.

## Enhanced Socratic Mode

An Enhanced Socratic Mode of teaching is observed at *Interaction 11.34,12.17 13.34, 19.23 & 23.40'* where the teacher engages with the participants within their small groups to check for understanding, develop ideas and pose questions about various aspects of the operation of the machine. This brings about intense dialogue and debate, all centred around the artefact and in particular around the epistemic fidelity and interactivity of the animation. An example of this dialogue is seen in the video footage at *'Interaction 24:54' .*In this instance, one of the participants has noticed the animation is out of date as a result to recent changes to the actual 'live' process. Three of the participants engage in defining the current operation of the machine and how it would be reflected in the animation. In doing so, they crystallise their own understanding of the operation and share this with the group to raise the overall level of understanding. Two more important dialogues feature between the class and the teacher and led to two significant learning moments recorded on video and confirmed later at interview. These can be seen in the video clips at *'Interactive 12.07'* and *'Interactive 28.50'* where critical points are explained by the teacher to a group of learners at their request. Both of these moments are representative samples of engaging learning dialogues which were enabled and facilitated by the artefact.

## Full Socratic Dialogue

At '*Discussion 5:47'* the detail in the animation is challenged, the animation is correct in its operation and is used to mediate a correct description. The whole group get involved in a collective debate about this particular challenge. The participant has offered their understanding in open debate. The animation is used to successfully refute this challenge. This is to the benefit and greater understanding of the whole group.

*Participant 1: what happens to DP when the cells block with yeast? Is the yeast flow not effectively dead-ended?*

*Teacher: "DP across cell should increase when yeast blockage increases because it is the difference between upstream and downstream pressure."*

*Participant 1: "Surely it should decrease as the pressure builds up behind the blockage?"*

*Participant 2: "Pressure should increase when the cells block up."*

*Teacher: "Let's test this out on the model. What does the model say?"*

*Participant 3: "The model shows the DP decrease which would suggest the model is wrong."*

Multiple conversations ensue. The participants engage, discuss and work through the proposition. It gradually becomes clear to all how the process works. After a time the conversation settles and the teacher explains;

*Teacher: "The blockage is like a dam. The pressure is measured between top and the bottom of the dam."*

The participants all agree they now understand the process and can fully conceptualise the function.

In the design review, Teacher Accompaniment was highlighted by Brown as desirable for effective use of the artefact and that the artefact design must be designed specifically to espouse the relationship between teacher and learner in a way that promotes dialogue. The exercises combined with the lesson plans were designed specifically for this purpose. The Training POST (see Design chapter above) ensured the design of the artefact, layout of the lesson plan and the trainer training were developed consistently and with the common goal of eliciting dialogue with the learners.

The evidence in the data revealed elements of the teaching style commonly termed Socratic Method. This included learning dialogue, dynamic group reconfiguration, enhanced Socratic mode teaching and full Socratic dialogue. The overall impact could be described as an Enhanced Socratic Mode as each of these themes was observed and subsequently confirmed in combination with the impact of the artefact as a semiotic mediator of itself and the elements of constructivist learning promoted by the semiotic mediator in the context of adult learning.

## Unforeseen Outcomes

The first part of the session was comprised of a quick recap, description and demonstration of the workings of the Pall Sep using the animation as a demonstration only. This part is of just as much importance for the peer to peer discussions and learner-teacher debates which follow it. *"It needs to marry the words with the animation. Blocks of words and blocks of animation are hard to reconcile. It's difficult to move from one to the other. You need to get the balance right. You can't do without either"* (ref Appendix D5: Interview Transcripts Section AA3). In this quote the participant who is one of the functional experts within the group recognises the need to set the context, the content and establish a learning goal or level of understanding to which the learners can subsequently aspire while they interact with the animation, the teacher and each other.

The participants highlighted functionality and user-friendliness as a key aspect of the success of the artefact as a teaching tool. However, some of the functionality was seen as obstructive or irrelevant. The section under 'Any other comments or suggestions' on the Trial Feedback forms contained suggestions such as *'better blend of text and animation would improve the presentation'* and *'sounds would add very realistic element to the animation'*. It was clear that differences between the animation and the actual machine stood out with the comment *'iron out minor snags'*. This difficulty with the functionality highlights the importance of recognising the impact of extraneous cognitive load as noted in the work of Pea and Gomez (see above). This attention to detail was further evident in

the interview transcripts such as (ref Appendix D5: Interview Transcripts Section BB1) *"there were inaccuracies in the process and the animation should be updated to reflect this"*.

The usefulness of the artefact was further evidenced by the requests to circulate it for use as a teaching tool, revision document and a trouble shooting guide. In one interview (ref Appendix D5: Interview Transcripts Section CC3) *'Can you email the program around? It would be really useful for fault finding. You could use the tool yourself. (other tools) are OK but this bridges a lot of gaps"*. In another interview (ref Appendix D5: Interview Transcripts Section BB3) *"you're more likely to re-visit this animation afterwards. If it's available, you can dip back into it any time. I think you're more likely to come away and re-visit with this kind of material. You can play with it after training..... I think you could load it up onto the PC at the panel. It's a tool that would be used again and again to remind yourself how the system work"*.

The feedback on functionality from the participants has a sub-text. Whether in the appreciation of the detail and the clarity it brought to the material, or as the area where they felt could improve their own understanding, there is a measure of self-evaluation by the learner. The participant has judged what they have learned and what they and others could learn with changes or improvements.

# Discussion & Conclusion

## Reviewing the research questions

To what extent did the research answer the research questions?

The questions check for what can be viewed as a three-pronged approach to setting up a rich workplace learning experience. The evidence from the video clips, the feedback forms and the interviews strongly support a view that a rich learning experience took place. Both the feedback forms and the interviews indicate the participants felt the subject matter was familiar yet complex. The way the artefact was employed to facilitate learning moments whether by direct interaction, peer dialogues or Socratic debates clearly indicates its role as a semiotic mediator. The participants were repeatedly observed to employ the artefact for 'playing', pointing and demonstrating, with no attempt to move away from the artefact and use pencil and paper. As noted above, the evidence from the interviews and the feedback forms supports this conclusion.

The question of constructed learning is equally important to the research. Did the participants construct their own meaning using the artefact? Easily recognised learning moments, references to 'play' and 'immersion in the material' indicate the participants were building understanding in their own terms. The dialogue between participants cannot be taken in isolation either. This indicates the construction of understanding in the participant terminology but with reference to a neutral mediator i.e. the artefact. Therefore, it can be concluded that in this instance the role of the mediator and the role of peer to peer dialogue are inextricably linked.

The Socratic mode ingredient added to the mix provided a catalyst for higher order learning and it is in these moments we see breakthrough learning. Socratic dialogue did emerge, an example of which is noted in the chapter above, recorded in the video clip at *'Discussion 5.47'*. The challenges arising from the participants during the trial could not have occurred without the interactive tool kit generating new and otherwise impossible outcomes.

## Interdependence and 'Triangular' relationship

However, the key to the research questions is the interdependence of these elements within the context of workplace learning. Constructivist learning, semiotic mediation and Socratic method teaching have been widely researched in the field of pedagogy. Indeed, even in the field of andragogy, works by Grissom in Computer Science learning, Brezis on Socratic Method Teaching in Medicine and Hundhauser with Algorithm Visualisation (see references above) are examples of research exploring each of these aspects in isolation from each other. What emerged from this piece of research is the effectiveness of the relationship between the student, the teacher and the artefact when the enhancements of constructivist learning, semiotic mediation and Socratic methods are

employed. Indeed, this three pronged approach can be imagined to have a ‘triangular' relationship given their interdependencies.

Let us consider further this triangular relationship in the context of workplace learning. It is clear that learners have constructed their own meaning using their prior knowledge and ‘experienced others’. They applied their own terms of reference to create meaning in a way which they had tried and failed to do in the past. This is the first side of the triangle. The artefact acts as a semiotic mediator for this process. It enables the participants to break through the barriers previously encountered. This is the second side of the triangle. Finally, to develop, enhance and correct understand, the Socratic mode emerges to test new knowledge and further facilitate the emergence the prior knowledge and experience of others, which is a key factor and strength of workplace learning. This is the third side and brings the learning process back, through open forum discussion and debate, to key factors influencing adult learning i.e. relevance, experienced others, prior knowledge and problem-centred learning orientation. Thus, the workplace acts as an adult learning enabler by setting the factors and conditions described by Knowles and Rodgers (see above) as key to adult learning.

## Teacher Accompaniment and Blended Learning

It is important to reference the first part of the session. As noted above, this part of the session was comprised of a recap, description and demonstration. All of the factors of adult learning are established at this point and even from the perspective of the psychology of adult learning, it is here the initiation, involvement, evaluation and essence of meaning are triggered as described by Rodgers above. It is clear in this area, as in all the findings from the data, that the workplace environment provides abundantly for these factors as well as providing material for the design of an effective semiotic mediator. Reflecting on the data, it is the opinion of the author that a blended approach to the lesson was important to its success. The accompaniment of the teacher using traditional descriptive methods of teaching in a didactic form was important to the participants as well as providing occasional instructional support.

## Workplace Learning Breakthrough

From the authors’ observations, the establishment of appropriate adult learning conditions in the workplace are well described in the literature. Further, the design and delivery of a semiotic mediator for workplace learning is understood across the more advanced industries. What was observed in this study was a transformational breakthrough enabling constructivist learning and enhanced Socratic mode teaching to emerge. The question now is why did this occur? In the opinion of the author an answer lies in Billets’ paper on Workplace Learning (see above). Billet supports Knowles and Rodgers in terms of highlighting the important factors in, and potential of, adult learning in the workplace. However, as noted above, he goes on to point out possible limitations of workplace learning and it is here we can look for reasons for the breakthrough learning as these barriers are

broken down by the impact of the three-pronged approach. The research trial successfully addressed three of the five barriers listed by Billet.

### Breakthrough A:  Access to authentic activities

Interview AA2 remarks *"changing the values was really good. Seeing the effect the different values have. You could change it and not worry."* This comment is representative of the opinion of all the participants that the interactivity aspect of the animation was worthwhile. In other words, it was an authentic activity for the participants to engage in. Billet speaks of a workplace learning curriculum which provides a pathway of learning from novice to expert. As the learner approaches the level of expert, it becomes more difficult to access authentic activities which can challenge the near expert and Billet proposes that technology may be the tool to provide those activities. The trial activity here provides evidence of this.

### Breakthrough B: Reluctance of experts

Billet notes how "expert workers may be reluctant to share their knowledge for fear of loss of status". There is evidence in the research data that in this case the artefact provides an appropriate segue for experienced workers to engage in learning dialogue. In interview CC3 as mentioned above, the participant notes *"it brings people in, in a cushioned way. It helps with the embarrassment. Some lads would be embarrassed with lots of years working in the area"*.  To understand why, Maslow provides the insight as the novelty of the animation causes gives rise to the 'delights of growth'.

### Breakthrough C: Opaque knowledge

Billet again looks to technology to provide insight in complex operations and there is much evidence in research data to show that the artefact has provided *'a very clear representation of a complex process'* as noted in one of the comments on the trial feedback forms

## Improvements with Hindsight

The research found positively on all three research questions. However, there were some gaps in the design and delivery. The tool clearly requires some skill to manipulate effectively and one of the local trainers remarked they found it confusing. Using it as a teaching tool is a significantly more daunting task than 'playing' with it as a means of gaining a deeper understanding of its subject matter. Also, researcher observation suggests the participants could have taken on deeper, more complex propositions as the early success in building understanding led to an appetite for greater knowledge.

# Conclusion

The purpose of this study was to investigate Workplace Learning facilitated by Semiotic Mediation. It explored the triangular relationship between adult learner, teacher and artefact in the context of manufacturing applications training. The artefact was designed with this intent, informed by emergent ideas based on a review of available literature and custom-built in collaboration with training teams local to the workplace. This resulted in a series of interactive animations, creating a visual representation of the subject matter.

To promote learning interactions between the learner and the teacher, the design of the artefact adopted constructivist learning principles. The research questions centred on whether rich learning experiences could be mediated by the artefact, whether knowledge is constructed by the learner using the artefact and if the lesson promoted inquiry dialogue over didactic teaching.

A trial learning session was carried out with 18 participants and this was recorded on video. Training evaluation forms, quiz sheets, feedback forms were completed and returned as research data for analysis. Semi-structured interviews were subsequently carried out to triangulate the data.

## Findings Summary

The data collected indicates a rich learning experience for all the participants, supported by multiple references to the level of complexity of the subject matter. The artefact was particularly strong as a tool for semiotic mediation. Interview feedback describes how attempts to teach this material in the past had proved to be quite a challenge. The impression of enhanced Socratic mode teaching came through strongly with rich learning dialogues being recorded on video. Reinforcement of this observation came through the interview transcripts. There were references to the way the artefact provided a gateway for participants to challenge propositions and build their both their own knowledge and the understanding of the assembled group.
Evidence of learning was clear both from the quiz results and the subsequent interviews. The feedback comments indicate breakthrough learning moments described in one instance as ‘pennies dropping all around the room’. Most of this occurred in the interactive phase of the trial.. This is supported by the interviews in both the references to ‘play’ and a desire to transfer and apply the same approach to other areas of complexity within the participants working environment.

## Learning Summary

From the literature, Grissom found that as the level of learner engagement with a simulation increased, so did their understanding (Grissom, 2003) and this has been validated by this piece of research for the context of workplace learning. He also posited that simulation technology is best employed in a scaffold learning environment where learners are allowed to correct their misunderstandings through discussion and interaction with fellow learners and instructors, and this

concurs with social constructivism as described by Vygotsky et al. The video footage from the trial and the interview data supports this in the context of workplace learning and concludes this to be a successful strategy for teaching of complex systems.

Hundhauser highlights the importance of dialogue. The social constructivists, such as Wetsch and Vygotsky, make a clear case for active and vibrant dialogue. Rochelle, Larkin and Bauer et al make a clear case for high quality graphical representation of the content. The work of Brown, Jarc and Grissom suggest interactivity is necessary to further enhance a social constructivist learning experience using technology based mediators such as graphical animations. These ideas resonated strongly through the research data and both the artefact and the teaching style were key to delivering the successful outcome.

Finally, Kirschner et al (Kirschner, 2006) argue that "learning by doing" is useful for more knowledgeable learners, but constructivist teaching techniques are not useful for novices because they promote behavioural activity too early in the learning process. Observation of the trial supports this as does the commentary from the interviews. The initial momentum was key to the success of the trial and this most likely would be absent with pure novices.

## Future Research

It is important to note that the sample set was too small to draw any major inferences or general conclusions. Further trials and research would be required to fully codify and validate the findings from this research. A full scale launch across a number of subjects would provide a broader data set to build further enhancements. The approach would benefit from refinement and extension into greater levels of complexity to test its limits. While the elements of semiotic mediation and learner dialogue were robust, more emphasis could be placed on the constructivist element of the learning as facilitated by the artefact and this would have to be carefully tested as it is potentially the most difficult element to deliver.