# Understanding the Weather:

# An Interactive Multimedia Program

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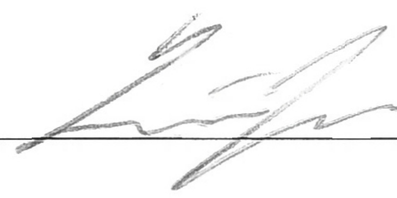
## Declaration:

I declare that this sub-thesis is my own work and has not been submitted in any other form for another degree or diploma at any university or other institution of tertiary education. Information derived from published or unpublished work of others has been acknowledged and a list of references is given.

I also declare that the design, construction and production of the CD-ROM submitted with this sub-thesis is entirely my own work, including all the artwork contained in the animations and all the voice-over scripting for the narrations. Background music and digital photographs are borrowed from legitimate sources, but schematic diagrams and text panels are entirely original.

Signed: 

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## Abstract

Existing educational material on basic meteorology is not sufficiently well packaged for the needs and interests of adult learners whose livelihoods are economically dependent on weather. The quality and quantity of information available does not match the high level of community interest in the subject, resulting in poor communication links between meteorologists, the media and the general public.

Most of the recent attempts to address this communication crisis have been limited to specific meteorological topics aimed at specific target groups. The QDPI "Managing for Climate" travelling workshop program has been uniquely successful in teaching basic weather science to rural Queenslanders, but the program lacks efficiency and includes minimal support/revision material. Little work has been done to package the contents of a general introductory meteorology course into a single, marketable teaching module for adults with a personal or vested interest in the weather.

The proposed solution is an interactive multimedia CD-ROM, whose purpose is to supplement the travelling workshops with a simple-to-use, comprehensive and thoroughly visual reference source. The design methodology involves a thorough analysis of misconceptions in meteorology, with a view to developing a product that presents the material simply, colourfully and accurately. A formal evaluation to measure the effectiveness of the finished product is yet to be carried out.

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# Chapter One: Introduction

Throughout history, the profound impact of weather on human activity has left a legacy of meteorological folklore and a rich store of experiential knowledge accumulated through generations of observation (John, 1998). Whilst much of this 'weather lore' is well founded, some is at best categorically false (Crowder, 2000) and there is a growing need for a more fundamental, scientific understanding of the weather among those whose livelihoods depend upon it (QDPI, 1997-2000).

The success of many industries is strongly linked to weather and climate trends, and an understanding of these trends is essential for optimal management practices and the minimisation of losses (Drought Policy Review, 1990). This is especially true for agriculture, where weather is the single most influential economic variable, capable of driving farmers to bankruptcy as it did in the 1982-83 Australian drought (Daly,1994).

Though there is an abundance of written material available on elementary meteorology (eg. Regano & Woods, 1998; Crowder, 2000), most of the material is pitched for a Northern Hemisphere audience, which makes it at best confusing, and at worst irrelevant to Australian learners. More significantly, very little has been done to package the subject into a form that will actively encourage adults in weather-sensitive occupations to access the information and use it productively.

In 1994, the Queensland Department of Primary Industries and Commonwealth Bureau of Meteorology attempted to remedy this problem by launching the *Managing for Climate* workshop initiative (QDPI, 1997-2000), an outreach program on weather

and climate education for residents and agricultural groups in rural Queensland. The success of these travelling workshops has been overwhelming according to the results of evaluation surveys (QDPI, 1998-99), but with an average of less than fifteen participants per class, the efficiency in delivering the information to the wider community without the support of an easy-to-distribute reference package is discouragingly low. Reference material currently supplied with the author's segment of the workshop is limited to a booklet with notes and diagrams (Regano and Woods, 1998), which fails to reproduce the visual richness of the oral presentation.

Although modern meteorology has evolved into a highly specialised, quantitative discipline, the essential principles underlying the subject are surprisingly easy to understand in the context of everyday experience. Regrettably, this inherent simplicity is not reflected in conventional meteorology education, and attempts to make the subject accessible to lay audiences are often tarnished by serious misconceptions and misleading simplifications (Fraser, 1994; Persson, 2000).

With the advent of new technologies in computer-aided learning, opportunities exist to substantially improve meteorology communication in Australia. Interactive multimedia offers great promise in this arena, with its capacity to enhance comprehension of intangible physical concepts and dynamic processes (Bell, 1999). Though it has the severe drawback of high production expense, the multimedia CD-ROM has significant advantages over other learning modes in so far as its potential to address the meteorology communication crisis is concerned. These include visual impact to encourage users, compactness and ease of distribution to remote localities, ability to provide user-feedback.

## Purpose of the Study

In the broader framework, the study is intended to contribute to the following global objectives of the QDPI *Managing for Climate* workshop initiative:

1) To promote a better understanding of the basic principles of meteorology and climatology within the rural community, and increase awareness of the services offered by relevant government departments.

2) To assist agricultural groups in rural Queensland to incorporate these services into their risk-management practices.

Specifically, The purpose of this study is

(1) to determine the most appropriate content for a self-guided educational supplement to the *weather* component of the *Managing for Climate* workshop program,

(2) to demonstrate that an interactive multimedia CD-ROM is the optimal way of delivering this content to workshop participants and to adult learners motivated by a personal or financial connection with the weather,

(3) to describe the details of a CD-ROM entitled *Understanding the Weather*, which has been designed in accordance with the above.

## Research Questions

The above points lead to two principal research questions, which the study seeks to answer in order to fulfil the stated aims…

1) What factors favour the use of an interactive multimedia program (over other learning modes) to supplement adult workshops in meteorology?

2) What aspects of style and content best facilitate learning about meteorology through this medium?

Answers to these questions are sourced from the literature and the author's experiences in the field.

## Method

Following the theoretical investigations outlined above, an interactive multimedia CD-ROM was designed from first concepts and developed to completion using Adobe PhotoShop 5.5 and Macromedia Director 6.5 for Windows. The module was created to provide revision material for *Managing for Climate* workshop participants, specifically targeting an adult audience with little or no background in meteorology. Topics covered include the origin of the earth's major wind regimes, pressure systems

and the weather map, cloud and rain processes, upper air charts and satellite interpretation. The completed CD-ROM is submitted with this thesis.

## Limitations

The study is limited by the shortage of available material on meteorology communication in Australia, and it has been necessary to make assumptions about the applicability of Northern Hemisphere findings. Evaluation of the CD-ROM is not presented as part of this thesis – such evaluation is ongoing.

## Overview of the Thesis

In the next chapter, a review of the literature is presented which summarises the existing problems in meteorology communication. Possible solutions are discussed, with arguments for and against the use of interactive multimedia as an educational aid. The target audience for a pilot multimedia program is defined and analysed.

Chapter three describes the completed multimedia program and the methodology behind its design. It gives a detailed discussion of the background science in an educational framework, with an in-depth analysis of common meteorological misconceptions and appropriate ways to tackle them. The lesson sequencing and overall navigational structure of the program are described and justified.

Chapter four is a summary of the existing problems, the aims of the study, the final outcomes and the methods employed to achieve them. As the study does not involve an empirical data gathering phase, the effectiveness of the final outcome cannot be ascertained without a formal, comprehensive evaluation. Such an evaluation is beyond the scope of this study and therefore not discussed in the chapter.

# Chapter Two: A Review of the Literature

## Background to the Problem

Despite a high level of community interest, the world, on the whole, is very poorly informed on matters meteorological. According to a recent survey of students at Universidad Europea de Madrid (Portela & Benito, 1999), 20% of the sampled population watch the television weather broadcast daily and 40% watch it at least once a week, yet 55% claim they do not understand all the terms used.

Results like this are not only discouraging from an academic viewpoint – they can have social and economic ramifications as well. An Australian study on the highly publicised 1997-98 *El Nino* event showed that poor communication and lack of meteorological background were responsible for serious misinterpretation of rainfall forecasts by both the media and the general public, resulting in erroneous management decisions and capital losses (Kestin, 1999).

Industries that are financially dependent on the weather have a very real need for more than just a superficial understanding of the subject. These especially include sport, tourism and primary industry, whose profit margins are exceptionally sensitive to local weather conditions and/or global climate patterns (see for eg, Drought Policy Review, 1990; Daly, 1994). An enormous sum of government money was spent in developing a micro-scale weather observation network for the Sydney 2000 Olympic Games. North Queensland tourism can suffer extraordinary financial losses from a single tropical cyclone impact. An El Nino event can ruin the Peruvian anchovy industry for an entire season and drive Australian farmers to bankruptcy. At present, the availability of suitable educational resources addressing the above needs falls well short of demand.

Educating the public in elementary meteorology is a complicated issue, not least because the desire to possess knowledge does not always match the motivation to acquire it. Though the majority of people would like to have weather *explained* to them, they do not necessarily want to be *educated*, as this too often involves hard work and stress (Wehry, 1999). In the past, the solution has been to simplify the information substantially, but this almost invariably spawns misconceptions and misleading explanations (Fraser, 1994; Persson, 2000). This defines the second part of the communication crisis in meteorology – the little that is taught is badly taught.

The scientific literature is riddled with incorrect and misleading information about basic weather processes (Fraser, 1994). At schools, tertiary institutions and even the Australian weather bureau training facility, references are frequently made to outdated conceptual models that have been known for decades to be incorrect, yet seem to

persist in modern texts and reference books (eg. Oxford Dictionary of Physics, 1996, 3rd edition; New Encyclopedia Britannica, 1994, 15th edition). Since teachers and instructors are often dependent on these references for their own self-education, the misconceptions filter down the hierarchy to the students and learners, who perpetuate the untruths through successive generations.

The school curriculum is partly to blame for adult ignorance in this field. In Australian secondary schools, meteorology is taught chiefly through the geography strand, which usually includes a lightweight treatment of weather chart and satellite interpretation (Finnie & Pope, 1999). Because of space restrictions in geography texts and lack of co-operation between meteorologists and geography teachers, the syllabus is sorely deficient in useful meteorological content (Finnie & Pope, 1999).

There have been a number of attempts to address the problems associated with poor communication of meteorology to the wider community. Portela and Benito (1999) have designed and trialed a meteorology course for journalism students, the rationale being that a better-informed media will improve the communication link between meteorologists and the general public. Though the initiative is too recent for substantial conclusions to be drawn, the study claims that short-term results "seem to be very promising."

The unique *Managing for Climate* workshop program is a joint initiative between the Commonwealth Bureau of Meteorology and Queensland Department of Primary Industries, which commenced in 1994 as an effort to help farmers incorporate weather and climate science into their management decisions (QDPI, 1997-2000). The

program draws on the expertise of meteorologists, climatologists and agricultural extension officers, who make regular expeditions to remote localities in Queensland to present full-day, interactive workshops on weather and climate.

The Managing for Climate workshop program is now in its eighth year of operation, with workshops held in about 20 rural locations annually. The workshops employ a well-researched constructivist learning philosophy (Yager, 1991), which draws heavily upon group dynamics and encourages class participation. Though feedback sheets (QDPI, 1998-99) confirm the success of these workshops for people with the foresight to attend them, attendance on the whole is disappointing, with a typical class size of 10-15 people from a community of several hundred target pupils. This apparent communication inefficiency is to some extent negated by the high propensity for information perceived as 'useful' to propagate within the rural community, but the sheer quantity of information covered in the workshops makes such propagation difficult to sustain without the support of high quality, easily distributed reference material.

A recent paper by Bell (1999) outlines some of the multimedia material developed by the Commonwealth Bureau of Meteorology to help learners visualise the complexities of the atmosphere. The material includes visualisations and animations of the atmosphere's fluid motion, satellite and radar imagery, and complex numerical fields. It does not, however, provide a sequenced module in basic meteorology.

There have also been several attempts at designing and implementing Web-based packages for self-learning. These include EuroMet (Zurita & Benito, 1999), a

package intended primarily to teach skills in satellite meteorology and numerical weather prediction; the Australian National Climate Centre's web-based information kit (Collins & Webb, 1999), which concentrates on the understanding of climate controls such as El Nino; and the American Meteorological Society's *Online Weather Studies* (Gear et al, 1999), a Web-based distance education module in basic meteorology for tertiary students.

## Interactive Multimedia as a Solution

Like all young technologies, interactive multimedia has its virtues and its flaws compared to more traditional platforms of delivery (Nash & Alexander, 1995). On one hand it offers a level of personalised tuition that no other packaged learning mode can compete with, but on the other, it is very expensive (not always justifiably so) and is not generally regarded as a substitute for a good teacher (Errington, 1997). The choice to launch *Understanding the Weather* as an interactive multimedia CD-ROM rather than a video, web site or textbook was based on the reckoning that for its particular purpose, the virtues convincingly outweigh the flaws. The literature documents several categories in which interactive multimedia outperforms other automated learning modes.

### 1). User Control

It is not always easy to justify the enormous expenditure and time investment involved in the production of a multimedia education package. In many cases a well-designed video (or even a textbook) might achieve the same learning outcome at a

small fraction of the cost (Yates, 1999). The key distinction is user control. With a video, control is limited to the on/off switch – it is the film production team and not the user who regulates the flow of information while the video is running (Zollman & Fuller, 1994).

The forte of multimedia is in transferring this control to the person operating the device. The user has the luxury to repeat sequences, to revise previous screens, to skip irrelevant sections and to progress at a pace appropriate to his/her needs (Stocklmayer, 1999; Bennett, 1995). Some designs allow a much greater degree of interactivity, with a fluid structure that adapts itself according to the user's responses (Bennett, 1995). It is ultimately not the physical act of pressing keys or clicking navigation buttons that yields the benefits, but the qualitative improvement in the user's cognitive processes (Stocklmayer, 1999).

It should be emphasised that the core lesson material in *understanding the Weather* is quite rigidly sequenced, allowing limited scope for exploration or interactivity (the reasons for this are detailed in chapter 3). However, the navigation buttons empower the user with greater control than a video could provide, and the final "dessert" menu allows unrestrained navigational freedom.

2). Performance Feedback

Feedback on the user's progress is an essential requirement of any teaching module that claims to be executable without the immediate presence of an instructor or mentor. A well-designed CD-ROM should monitor the pupil's understanding by providing appropriate and adequate feedback at regular stages in the learning process

(Kennedy & McNaught, 1997). This may take the form of visual cues in quizzes or games, or it may be implicit in programs whose structure changes according to the user's input.

Performance feedback is much more difficult to implement in other audiovisual media. It has no place at all in video, and its inclusion in web-based software is limited by programming difficulties, which increase markedly with the number and complexity of interaction types (Kennedy & McNaught, 1997). *Understanding the Weather* contains two interactive quiz sessions providing real-time feedback to user input.

3). Ease of Access and Distribution

Farmers form a large proportion of the target audience for *Understanding the Weather* and interactive multimedia has particularly obvious advantages in the remote locations where these people live. At the time of writing, Internet links across the Queensland interior were very slow (QDPI, 1997-2000), making a web-based product difficult to justify. The absence of academic libraries and university support facilities discourages self-tuition in the bush, and agricultural extension officers are generally only found in the larger provincial towns. *Managing for Climate* workshops typically visit any single locality only once per year, and the timing may be unsuitable for the majority of potential participants.

Whilst it would be naive to claim that multimedia instruction is a fair substitute for these absent learning modes, it offers speed, durability and flexibility of access, making it highly suitable as a self-paced learning tool for people in remote areas.

When used in conjunction with *Managing for Climate* workshop presentations, a multimedia CD-ROM can provide high quality reference material for workshop participants, as well as non-participants caught in the wave of post-workshop discussion propagating through the community.

Historically, the biggest stumbling blocks in meteorology education have been the mental gymnastics required to visualise motion on a rotating sphere, and the numerous misconceptions arising from a poor understanding of the subject matter by the educators themselves (Fraser, 1994; Persson, 2000). This makes meteorology unnecessarily one of the most difficult and poorly taught subjects in the scientific curriculum.

Interactive multimedia offers a solution to both of these stumbling blocks. The 3-dimensional visualisation difficulties plaguing elementary meteorology can be largely overcome by clever use of computer animations (Phillips & Jenkins, 1995). Topics that have taken the author an entire morning to conceptualise in front of a class (QDPI, 1997-2000) can be covered in minutes using synchronised sound and graphics, with the additional benefit that the topic can be revised at the user's discretion. Well-designed graphics have tremendous teaching power. In an educational design study of the function and structure of the human heart, Szabo (1990) found that the addition of graphics to a text-based teaching module resulted in "significantly better performance in visual and conceptual criterion tasks."

Weather phenomena are generally difficult or impossible to simulate in a laboratory environment, so in many instances, computer animation is the sole alternative to a

purely theoretical approach. The controversial issues facing the Dry Labs initiative (Pearce, 1996) become largely irrelevant in these situations, because traditional laboratory alternatives do not exist without prohibitive expense.

Many of the common misconceptions in meteorology have evolved because of a natural tendency to use over-simplistic analogies when concepts are unintuitive. A simple, flawed analogy that provides the correct answer to a conceptually difficult problem is a very attractive teaching tool, one that has been conveniently adopted by teachers and authors with only a superficial knowledge of the subject (Fraser, 1994). Examples include the merry-go-round model of the Coriolis effect (Persson, 2000) and the greenhouse analogy for global warming, both of which yield qualitatively correct answers for the wrong reasons.

An advantage of multi-media presentation is that it can capitalise on its visual animation capabilities (Johnston & Peat, 1996; Errington, 1997; Phillips & Jenkins, 1995) to tackle the less popular, more accurate analogies, without sacrificing clarity of understanding. A detailed analysis of the common misconceptions and omissions in modern meteorological literature is given in Chapter Three.

The essence of interactive multimedia is to combine the benefits of more traditional learning styles into a self-teaching module that imparts knowledge through stimulation of all sensory channels. Its many advantages make it seem the perfect learning machine, but in practice there are trade-offs. To demonstrate that a multimedia CD-ROM is the most appropriate mode in which to present revision material for adult workshops in meteorology, it is necessary to show that (a) the

advantages outnumber those of other modes and (b) the trade-offs are either insignificant or irrelevant in the context of this study.

To begin with, empirical evidence is needed to verify that multimedia actually helps people learn. In his paper entitled *Multimedia Information and Learning*, Najjar (1996) investigates the learning outcomes of multimedia instruction in a variety of situations, drawing upon the empirical work of several authors. He finds that compared to traditional classroom lecturing, multimedia proves superior in several special categories, namely

1) Capacity for interactivity, which tends to be greater with multimedia instruction. Najjar cites a 1990 doctoral thesis by J.Y. Stafford, in which it was concluded from a statistical examination of 96 learning studies that interactivity is associated with the acquisition and retention of knowledge over time. Note that interactivity is not possible using a video or textbook as the learning mode.

2) Control over learning pace, which is absent in a typical classroom situation. The self-paced learning environment offered by multimedia is far more adaptive to the individual's specific strengths and weaknesses, allowing progression at a user-defined pace. Note that self-paced learning is just as easily accomplished with a textbook (and at much lower cost), but a textbook lacks most of the other assets discussed (eg. interactivity, novelty value, visualisation capability). Self-paced learning is not generally possible with a fixed-speed videotape.

3) Novelty value, which though not directly affecting content, improves comprehension through increased stimulation and interest. Nearly 40 multimedia studies (eg. Clark & Craig, 1992) have found that learning improvements achieved through multimedia instruction taper off fairly strongly after eight weeks, suggesting a 'waring off' of the novelty value. Interactive multimedia possesses a higher novelty rating than any traditional learning mode.

Najjar isolated a number of specific situations in which multimedia was empirically shown to help people learn, of which two are presented here. The first is when the individual media elements support "dual coding", a state where the mind can process information simultaneously through two distinct sensory channels. Also known as referential processing, this phenomenon occurs when, for example, a voice-over narration plays in the background of a pictorial animation sequence. Several authors (eg, Mayer & Anderson, 1991) have shown that referential processing in multimedia instruction has an additive effect on recall, thus increasing learning efficiency.

The second situation occurs when there is redundancy in the media elements, for example, a text panel describing hurricanes alongside a photograph of crashing waves and swaying palms. In almost all cases, such redundancies have been shown to improve comprehension compared to a single medium in isolation (Mayer & Anderson, 1991).

The disadvantages of multimedia documented in the literature fall essentially into three categories. The first and most obvious is cost. Multimedia authoring is intensive and time consuming and professional developers accordingly charge very

high fees (Yates, 1999). A case must be very well made to justify the expenditure, and a cheaper alternative is often available with only minor compromise in educational outcome.

For the special circumstances of this study, the open-market expenses associated with multimedia production are not relevant. All stages of production are undertaken by the author, who has developed basic skills in multimedia design through coursework training. In practical terms, this makes the multimedia program a more efficient option than a videotape or other delivery mode, simply because it avoids the necessity for the author to learn a completely new production technique.

The second disadvantage category is technology-related. Multimedia instruction requires a modern computer with high processing speed and a CD drive. Not all Australians have access to a computer, leave alone a fast computer. In the current technological climate, distributing educational material via a CD-ROM will inevitably discriminate against those without adequate computer armoury.

On the other hand, technological progress and market forces are rapidly bringing down the prices of computers, which "is likely to result in a large increase in the number of households able to use multimedia technology" (Del Papa & Ferrari, 1999). Given the explosive evolution of the technological age, it is appropriate to address the market of tomorrow when designing and defending a product. The disadvantages of multimedia associated with restricted computer access are therefore not a serious consideration, since the passage of time will quickly nullify them.

The third popular criticism of multimedia is that pupils are denied the benefits of peer interaction in a supportive classroom environment, where they can ask questions and seek individual guidance from a knowledgable instructor. Though well founded, this criticism is once again inconsequential to the present study. The purpose of *Understanding the Weather* is to produce the best possible support material for a classroom-based workshop program with real teachers, not to produce a stand-alone kit for pure self-study. In the words of Del Papa and Ferrari (1999), it is "the synergy between the teacher and the self-study material that produces the best results." To be sure, the CD-ROM will undoubtedly have educational value in its own right, but its full potential can only be harnessed when it is used in conjunction with the workshops for which it was designed.

**The Target Audience – Adult Learners**

The decision to develop a CD-ROM rather than a video was influenced in part by the limited success of a mixed media package called *Farming a Sunburnt Country*. Developed jointly by the Weather Bureau and the Department of Primary Industries to educate farmers about the *El Nino* phenomenon, this video package suffered by its "inflexible delivery mode," and was perceived by many farmers as providing more entertainment than educational value (Lee, 1998). Although *Understanding the Weather* is a much smaller package produced on an incomparably low budget, its interactive interface and simplicity of content are less likely to cause the same problems.

According to Brookfield (1986), adults tend to be "life-centred" in their learning habits, with experience being a major resource in learning situations. While it is obviously impossible to incorporate the experiences of every Australian adult into an electronic teaching kit, it *is* possible to utilise concepts and analogies that draw upon the common, collective experiences and existing knowledge of Australian people. According to Daniels and Chamala (1989), communication with farmers is more effective when information is presented to emphasise the compatibility of new and existing knowledge. That *Farming a Sunburnt Country* did not attempt to relate its preachings to the needs and experiences of the target audience was one of its major downfalls (Lee, 1998).

One of the principal distinctions of adult learning is that it tends to be voluntary, and learning is most effective when there is a "perceived, immediate need" (Hiemstra & Sisco, 1990). This fact does not need to be explicitly addressed in the design of *Understanding the Weather*, because the target audience (adult learners motivated by a personal or financial connection with the weather) automatically perceive an immediate need. They do not require the same motivational tactics as, for instance, a group of farmers asked to study the El Nino phenomenon without being first educated about its relevance to their livelihoods (Lee, 1998).

The perception of immediate need and relevance is just one of the prerequisites for successful adult learning. Keller (1987) summarises a strategy that calls additionally for *attractive content* to maintain the learner's attention, *encouragement* to stimulate confidence and *satisfaction* upon completion. (The module described herein strives to satisfy each of these criteria. Full-colour animations provide the basis for the first

criterion, whilst extensive feedback in the quiz sessions addresses the second. The third criterion - user satisfaction - cannot be properly gauged until the module has been formally evaluated).

Though there is an abundance of literature available on the subject of adult learning, much of it is concerned with traditional contexts involving groups of adults in workplace or classroom settings (see, for example, Greeno et al, 1999). This type of research is only marginally relevant to the self-directed learning approach promoted by a CD-ROM. In his comprehensive paper on computer-based adult training, Szabo (1990) highlights a number of important issues specific to self-directed learning and discusses some of the advantages of the electronic delivery mode over more traditional group-based learning platforms.

The key, according to Szabo, is to focus on the adult training requirements that "can be influenced or controlled by trainers." One of these requirements is sufficient learner control. Adults learn better and retain information longer when they are given control over what they learn (Szabo, 1990; Hiemstra, 1998). A regimented classroom environment does not automatically support this requirement without conscious, strategic efforts on the part of the teacher/facilitator. Nor does it support the need for self-pacing, which, according to a study of college students by Kulik et al (1980), reduces the required instruction time by 20 to 50%.

The inclusion of revision exercises in adult training modules has been shown to improve comprehension, and it is widely believed that positive reinforcement after each exercise will improve subsequent performance (Szabo, 1990). This is

particularly true for incorrect responses when encouragement is most needed. (*Understanding the Weather* contains two sets of revision exercises designed to address this need, the feedback taking the form of hints which guide the user to the correct answer through his/her own perseverance).

Another significant advantage of self-directed, computer-based instruction is the flexibility of study time and location. The work-a-day schedule of an employed adult is often incompatible with the schedules imposed by teachers and trainers (Szabo, 1990), especially when these involve regular class meetings at fixed locations and times. Evidence exists that learning time can be reduced by up to 30% through the use of instructional technology, which allows the learner to complete a significant proportion of his/her training individually (Szabo, 1990).

It is pertinent to differentiate between the needs of different adult age groups as well. The target audience for *Understanding the Weather* happens to consist largely of middle-aged to retired farmers, many of whom fall into the "elderly" category whose learning habits differ somewhat from those of younger age brackets. According to Drake (1999), three in four elderly adults from Nordic countries seem not to participate in organised, classroom-based learning, reflecting a need to "capitalise on alternative learning contexts and non-instructional approaches." The reluctance to participate does not reflect lack of motivation or ability, but rather a preference for more open, self-directed learning modes.

**Summary**

The world is poorly educated in meteorology, despite high public interest in the subject and perceived relevance to many industries. The problem is largely due to the scarcity of good quality educational material and the absence of marketing initiatives to encourage people to use it. The QDPI *Managing for Climate* initiative has confronted the problem with its successful travelling workshop program, but in isolation, the workshops have provided an unfavourably low percentage penetration into the target population.

A multimedia CD-ROM has been proposed which addresses the significant shortcomings of modern meteorology education and presents the content accurately and colourfully in a form suitable for novice adult learners. In spite of it's disadvantages (chiefly production cost and computer access limitations in the community), multimedia is argued on several grounds to be the optimal form of support for *Managing for Climate* workshops, with the propensity to improve the overall penetration of quality weather education into the wider community.

# Chapter Three: Design Methodology

Although many exciting weather phenomena can be described and explained independently of one another, elementary meteorology is very much a progressive discipline, where each new concept is built on a clear understanding of the previous one. It is therefore desirable for the proposed teaching module to guide the user through a linear sequence of background lessons, before exposing them to some of the more novel topics in meteorology. The core subject matter that forms the basis of these lessons is not trivial and necessarily comprises the bulk of the information contained in the module.

The challenge for the designer is to present the core material as simply, efficiently and colourfully as possible, without sacrificing scientific accuracy. This chapter outlines the methodology used to achieve the above outcome in the face of the numerous misconceptions plaguing the popular scientific literature. Though the end product is chiefly the result of the author's own analysis, it has been moulded substantially by contributions and feedback from peers (both scientists and non-scientists). Unfortunately, it has not been possible (in the available timeframe) to trial the product on users in the rural environment.

## Information Content

### Lesson 1: The General Circulation

The starting point for most introductory meteorological textbooks is a discussion of the large-scale motion of the atmosphere across the planet. Though this topic requires

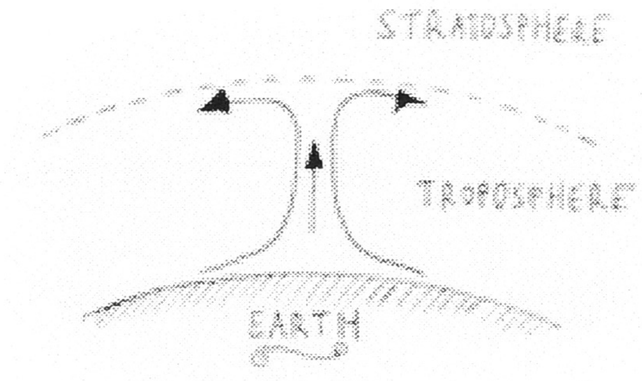
a generous supply of left-brain energy for 3-dimentional visualisation, the concepts underlying the theory are generally intuitive and easy to understand.

Consider the first of these concepts – *hot air rises*. According to a survey conducted in the United States, 96.7 percent of Americans believe this statement to be true (Stocklmayer, pers.comm.). For the benefit of the remainder, it's easy enough to give it some background: Air expands when it is heated just like the mercury in your thermometer. This means a litre of hot air weighs less than a litre of cold air, so when the two are in each other's company, the hot air floats to the top like a rubber duck in a bathtub.

Explaining difficult concepts in terms of simpler, more familiar ones is a method employed extensively in the module. Since there are no "ultimate truths" in the universe but only a hierarchy of increasingly refined models (Stocklmayer, pers.comm.), there is nothing impure about teaching concepts through simple analogies that draw upon the user's existing knowledge and experience.

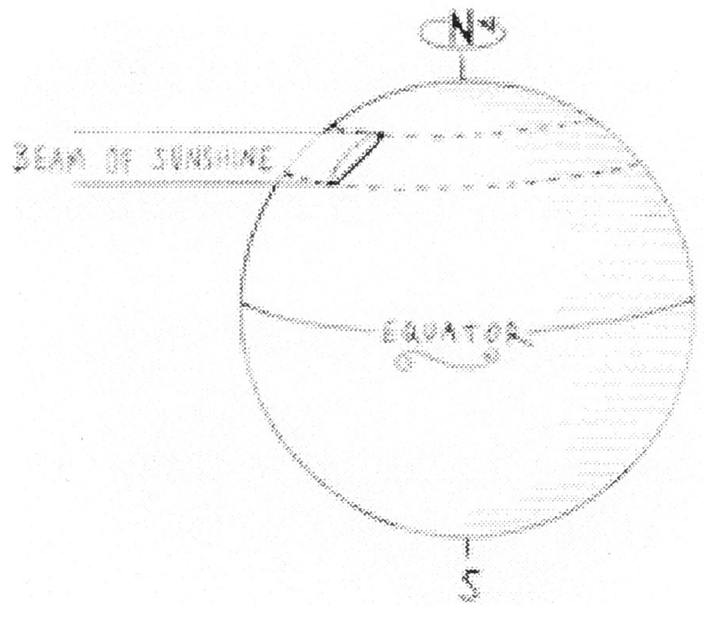
There are several analogies one can use to set the scene for the Hadley circulation, the aim being to convince the user that uneven heating causes wind. A popular one is the local drafts felt in a large, closed room when a fireplace is kindled (QDPI, 1997-2000). My preference is the sea breeze model, because in addition to explaining the origin of wind, it throws light on an interesting weather phenomenon that would otherwise require separate treatment. Efficiency is a key issue in a design environment where every megabyte of disk space carries a monetary cost.

An important omission is frequently found in textbook discussions of the Hadley circulation (see, for example, Crowder, 2000; Wright, 1994). It is not at all obvious that hot air rising above the equator should suddenly turn poleward when it reaches the top of some arbitrarily defined layer in the atmosphere. Why doesn't it just keep going up?




The diverting action of the stratosphere needs to be clearly explained in terms of familiar concepts before the Hadley cells are introduced. Most adults are at least vaguely aware of a thing called the ozone layer, which chews up UV rays and stops us from getting skin cancer. This vague familiarity is all that is required to explain the sudden rise in temperature of the stratosphere, which acts like a lid to divert rising air.

Another source of confusion is the origin of the enormous temperature difference between equator and pole. Whilst the obliquity of sunshine is the correct underlying cause (and indeed the reason advocated in the module), it is not simply a matter of calculating the area of the spot where the light beam strikes the earth. Over a 24-hour period, the heat from this beam gets smeared across the entire latitude belt, and the correct quantitative result can only be obtained from a mathematical integration.




Of course a CD-ROM for weather novices is no place to discuss calculus, so the best compromise can be reached via an animation in which the earth is seen to rotate beneath the shining beam. At least an astute user might then notice that a single patch of ground doesn't get baked for eternity.

Explaining the earth's major wind systems requires recourse to the *Coriolis effect*, a phenomenon so notorious for its misleading analogies that even the Oxford Dictionary of Physics (1996, 3rd edition) and Encyclopedia Britannica (1994, 15th edition) fail to explain it correctly. In his recent article in Weather Magazine, Persson (2000) describes the downfall of three popular textbook analogies still used today to explain the deflection of a moving air parcel on the surface of a rotating globe. These include the apparent curved path of a ball thrown from a merry-go-round, the erroneous conservation of velocity principle and the Foucault Pendulum model.

Despite its elegant mathematical formulation, the correct theory of the Coriolis effect is extremely difficult to explain to a lay audience from first principles. The trick is to explain it not from first principles, but in terms of every-day experiences the user is likely to have had.

The effect is a direct consequence of the law of *conservation of angular momentum*, which relates the mass distribution of a freely rotating system to its angular speed. Fortunately, there are several good work-a-day examples of this law in operation, the most appealing being the ice-skater or ballerina, who can adjust her rate of spin by extending and contracting her arms. It is a surprisingly simple process to relate this result to the deflection of winds upon the surface of the rotating earth.

The Coriolis effect is the basis for the respectively clockwise and anticlockwise spiralling of winds around Lows and Highs. But it is categorically wrong to say (as many textbooks do) that without the earth's rotation, air would plunge directly into a low-pressure system. This is equivalent to saying that the earth should plunge directly into the sun because gravity tugs it in that direction. The 'suction' of a low-pressure centre provides the centripetal force necessary to pull the winds into a spiral orbit. The Coriolis effect simply guarantees that this orbit will be clockwise in the Southern Hemisphere.

Lesson 2: The Weather Map

This lesson is free from conceptual model building problems, being largely descriptive and concerned more with pattern recognition than with physical concepts. Reading a weather map is best learned through practice, so the animations are reinforced by a set of interactive revision questions, which bring together all the material covered in the first two lessons.

Feedback is provided for all question attempts via a pop-up window, with a succession of hints following incorrect answers and a reinforcement of key concepts

following correct ones. The unit is deliberately hard-wired to prevent continuation until each question is answered correctly, though over-riding navigation buttons allow exit from the session at any time. The quiz is followed by a page of lightweight trivia, mainly for entertainment value.

## Lesson 3: Highs and Lows

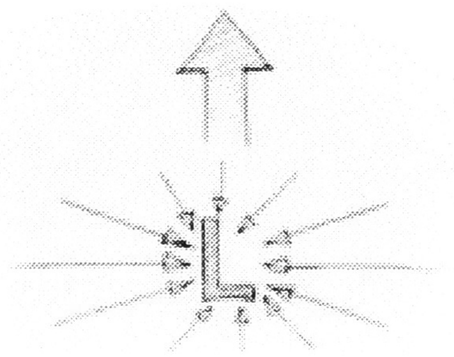
This lesson begins with another technical hurdle – the misconception that clouds form because of a difference in the moisture holding capacities of cold and warm air. Because this model infallibly gives the right answers (for the wrong reasons), it remains standard in most textbooks today and is still being taught at the Bureau of Meteorology training school. The correct explanation is unfortunately not nearly as intuitive (a temperature-dependent equilibrium between the rates of condensation and evaporation of water), but this does not justify the perpetuation of scientifically flawed reasoning in the literature (Fraser, 1994).

Once again, the power of analogy provides a convenient escape route. There is a plethora of every-day occurrences that mimic the condensation process which occurs during cloud formation. Examples include the fogging up of your windscreen on a damp, chilly night, the cloudiness of one's breath during cold weather, the morning dew.

These phenomena differ from cloud formation only in the nature of the cooling process, which is itself a source of confusion: Rising air cools because it expands adiabatically with diminishing pressure (Wilkie, 1988; Gedzelman, 1980), not because it is chilled by contact with cold, high-altitude air. However it is not

incorrect, nor misleading, to simply state that rising air cools as it is lifted to a colder altitude (as per the module). The user should indeed be encouraged to draw a connection between the temperature change of a rising air parcel and the temperature profile of the atmosphere, because the same thermodynamic processes are responsible for both.

Textbook descriptions of the workings of a low-pressure system are at best confusing and at worst entirely wrong (Adams, 2000). It is commonly stated that air converging into a Low is forced to rise because there is nowhere else for it to go (see for example, Wilkie, 1988).



This statement is only true if an external mechanism exists to sustain the low pressure. Otherwise the converging air could just as easily pile up in the centre until the low pressure disappears. This qualifying statement is frequently ignored, to the confusion of any thinking pupil.

Oddly enough, the principal sustaining mechanism is often the latent heat released during cloud condensation, which wouldn't exist without the Low in the first place. So while it may be said that low pressure causes rain, it is just as correct to say that rain causes low pressure.

Lesson 4: Cloud Processes

Aside from the already discussed misconceptions about cloud condensation, the methodology behind this lesson is relatively simple, with no further conceptual obstacles presenting themselves. Latent heat is explained using a counter-analogy (the absorption of heat by a pot of boiling water) and convection is described in terms of buoyancy concepts that the user has already been introduced to in previous lessons. Care was taken to present convection as a continuous overturning of the atmosphere, rather than a simple model of hot air rising, which does not explain the cellular cloud patterns that result.

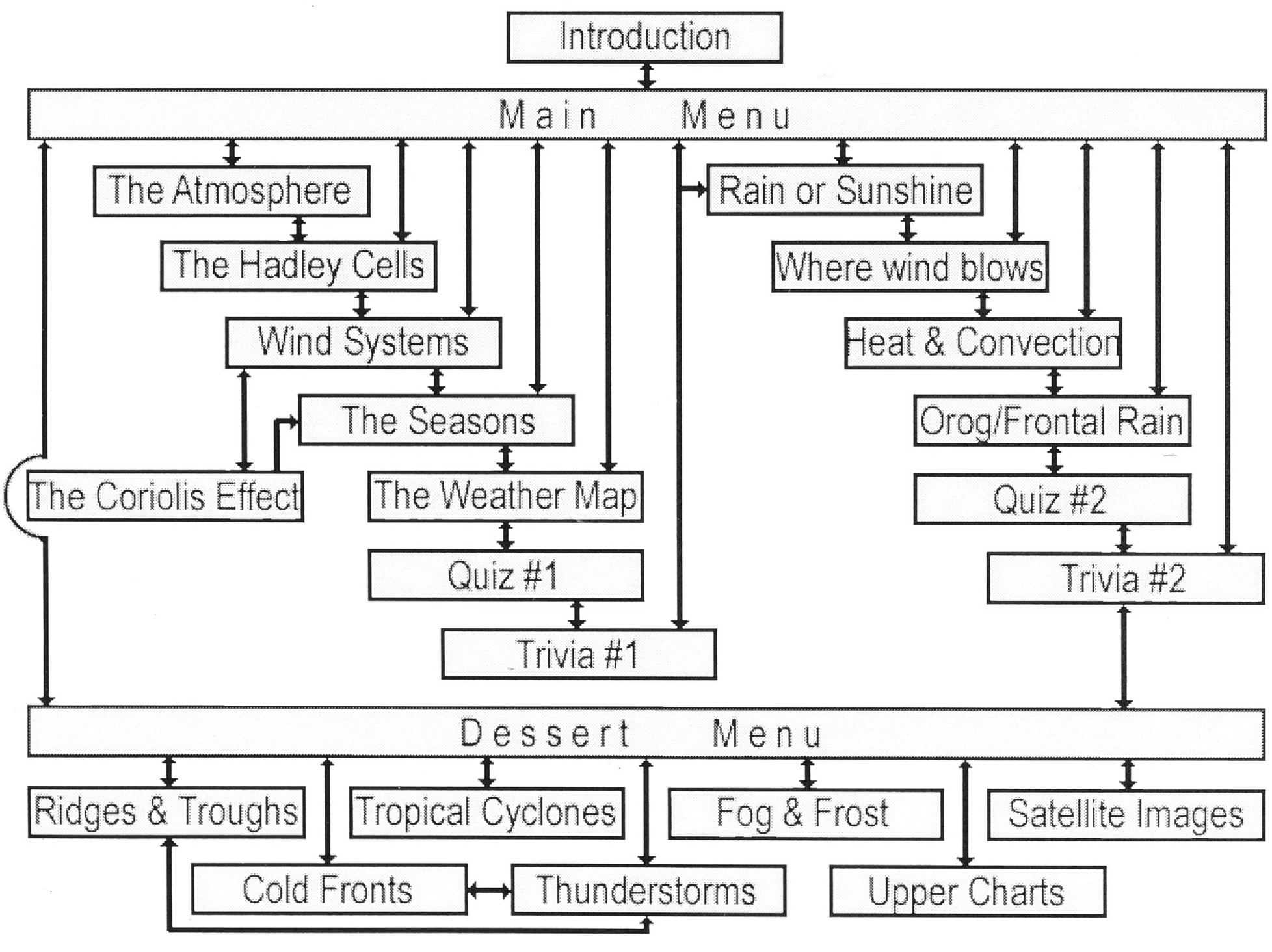
In the case of orographic cloud, the only real challenge was the explanation of uplift caused by the slowing of winds across the coastline. Though not incorrect, the analogy of a car pile-up in a traffic jam (used in the module) is not entirely satisfactory, because cars don't rise when they get squashed into a small space.

Much of the material covered in lessons 3 and 4 is reinforced in the second interactive revision session, which follows the same format as the first one. After a short page of entertaining anecdotes, a *dessert menu* is presented, where the user has several branching options that lead to a lightweight treatment of some of the more novel meteorological phenomena. Among these, only *Fog & Frost* presents a potential misconception.

In the explanation of frost, the well-known 'blanket' analogy is used to describe the suppression of ground cooling on a cloudy night. The blanket model is criticized by advocates of correct reasoning in meteorology (Fraser, 1994), but the author

challenges this view in the special case for which it is used in the module. While it is true that the mechanism by which a blanket inhibits cooling is different from that of a cloud deck, the net result can in both cases be attributed to the "trapping of heat." In the case of a blanket (and for that matter a greenhouse), the suppression of convection currents results in the trapping of air and therefore the trapping of heat carried by that air. In the case of cloud, heat is trapped in the sense that most of the infrared photons leaving the ground do not make it past the cloud deck before being absorbed.

**Structure and Navigation**




The flow chart above describes the structural framework of the interactive multimedia CD-ROM *Understanding the Weather*. The structure is for the most part a mixture of

referential and branched-linear (Bennett, 1995), but flashing navigation buttons guide the user along a sequential, linear pathway through almost the entirety of the core material. This constitutes all the boxes above the *Dessert Menu* bar in the diagram, which have been sequenced in a logical order that gradually builds the knowledge base required to explore the more freely navigable Dessert Menu topics. The flow chart does not show the breakdown into the four basic lesson headings described in the previous section - it shows only the sub-headings. *The Coriolis Effect* is included as an optional detour from the main lesson sequence, since it is a rather specialised topic and may destroy continuity if treated as core material.

The delivery style of the core material is predominantly full-colour graphics and animation with voice-over narration. Though narration can be distracting in certain situations, it has several important advantages over a text-based delivery. According to dual coding theory (Najjar, 1996), the brain can assimilate picture and sound simultaneously, so a narrated picture-story offers greater learning efficiency than a series of text panels with a pretty background. The nine core units in *Understanding the Weather* typically take 1-3 minutes each of playing time, yet collectively they cover as much material as a small textbook.

The absence of text panels also has the advantage of allowing the entire screen to be devoted to pictorial sequences. Even a stationary graphic, when composed properly, can convey as much information as an entire page of text.

Finally, text is boring. It is hard to justify the crippling expense of a multi-media software package, if the bulk of it could just as easily have been pasted onto the pages of a book.

Though the module has no prerequisites and is largely self-contained, it is assumed at this point that the user has attended a *Managing for Climate* workshop session (the study is trying to promote the use of multimedia not in isolation but as an accessory to classroom-based instruction). The material contained in the CD-ROM forms the subject matter of the workshops, but the CD-ROM itself is not integrated into the workshop agenda. Rather, it is included as reference material handed out to participants at the beginning of the day, together with course notes, educational brochures and information on services provided by DPI and the Weather Bureau. Prior to operating the CD-ROM, the user will have had considerable practice in tackling simple weather exercises, thus negating the need to include excessive interactivity in the multimedia program.

One proceeds through the nine core units at one's own pace, repeating, skipping and revising as necessary. The navigation buttons allow the operator to quit the program or escape to the main menu at any time, the menu serving as a link between any two units in the module. Gentle background music is included in the narrative sequences to promote relaxation and create a pensive mood. The music is deliberately simple, uniform and inconspicuous, adding warmth to the narration without directing attention away from the lesson content. Those who find the music distracting have the option to turn it off.

Two sets of revision questions interrupt the lesson sequence, in each case to consolidate the information presented in the preceding units and also to provide relief from the potential monotony of narration. As outlined in the previous section, feedback from answers is provided either by hint balloons or by reinforcement of correct reasoning, in the case of a correct answer. Trivia pages exist purely for entertainment value.

The Dessert Menu is displayed after the final set of revision questions and trivia have been completed. At this point the operator has complete navigational freedom, each option linking to a self-contained, three-page description of a particular weather phenomenon. The Dessert Menu items are text-based, mainly to avoid narration over-kill. They are accompanied by informative, mood capturing photographs, and carefully selected musical tracks to complement the theme. The units on upper chart and satellite interpretation are adapted from the post-morning tea component of the *Managing for Climate* workshop agenda.

This completes the discussion of design methodology. A summary of conclusions, limitations and recommendations is given in the next chapter.

# Chapter Four: Summary and Conclusions

Existing initiatives to address the inadequacies of meteorology communication to the wider community include travelling workshops, which seek not only to educate rural residents in weather science, but also to provide an opportunity for them to exchange ideas with urban scientists in their own familiar territory (QDPI, 1997-2000). Though highly successful, these workshops suffer from the inefficiencies of small classes and infrequent visits, and accompanying reference material is not of sufficient standard to assist propagation of the information through the rural community. Other initiatives have only been successful for specific meteorological topics aimed at specific groups.

The proposed solution is an interactive multimedia CD-ROM entitled *Understanding the Weather*, whose purpose is to package the basic principles of meteorology into an efficient self-teaching module to supplement adult workshops in elementary weather science. The methodology employed to achieve this outcome involved a 'devil's advocate' analysis of the meteorological literature, bringing forth any misconceptions or topics of potential confusion to the novice learner. The CD-ROM was then created on the premise that the material ought to be presentable in a simple and colourful way, without compromise of scientific accuracy.

The effectiveness of the finished product in terms of the stated aims cannot be ascertained until a formal evaluation is carried out. It is hoped that such an evaluation will be conducted in due course. Though the module has not yet been trialed in the rural setting for which it was largely designed, parts of it have been adapted into a presentation aid for *Managing for Climate* workshops, with encouraging feedback so

far from workshop participants and QDPI extension staff. This feedback refers only to the completed product – it was not used as formative input during the design stage.

While *Understanding the Weather* makes considerable ground in encouraging a scientific view of the atmosphere, it fails to confront more traditional approaches to weather forecasting involving signs from nature, which constitute a very important part of the meteorological knowledge base in the bush (John, 1998). Regardless of whether such methods are scientifically viable, Brookfield (1986) reminds us that the learner's own experience should be "a major resource in learning situations," and an attempt should therefore be made to reconcile the new and the old, rather than tossing one away and starting with a clean slate.

Another shortcoming of the CD-ROM is that it fails to make a connection between the subject matter and the specific needs of the user. Though this may seem at first to be an insurmountable task, it would, in principle, be possible to at least include examples or case studies for a handful of commonly encountered agricultural applications. Such a project would, of course, be beyond the scope of a Masters sub-thesis.

In closing, it is pertinent to point out that although the package was designed with novice adults in mind, there is nothing inherent in the module that would preclude its successful use in schools. The dynamics of a high-school classroom are, of course, incomparable to the typical learning environment of an independent adult, so motivational issues will play an important role. However, the lessons are pitched at a level perfectly suited to a typical year 11 or 12 physics student, and it would be an unfortunate loss if this avenue were not explored in the fullness of time.

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## Appendix: Technical notes for operation of CD-ROM.

The CD-ROM *Understanding the Weather* is submitted in hybrid format, suitable for both Windows and Macintosh platforms. The program occupies about 140 MB of disk space, and will only run on computers with a standard monitor display of at least 800 x 600 pixels.

To run the program, simply load the CD-ROM onto your CD drive. On newer machines, the program will start automatically. On older machines, double-click on the CD icon that appears on your desktop (Macintosh) or in your file explorer (Windows). Then double-click on the "Weather.exe" icon. The program will run more smoothly if you first copy it to your local hard drive. For large monitors, a full-screen display can be obtained by setting the monitor resolution to 800 x 600 pixels.