"Fun with Polymers"

Development of Interactive Multimedia and Practical Polymer Science Programmes

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Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously, in its entirety or in part, submitted it at any university for a degree.

DATE

Opsomming

Multimedia was die gonswoord van die vorige dekade. Elektroniese leer is die gonswoord van die nuwe dekade. Beide hierdie konsepte het, en is nog steeds besig, om die wyse hoe kennis en inligting, plaaslik en wêreldwyd, aan studente oorgedra word, te verander.

Suid-Afrika, as deel van hierdie tegnologiese veranderinge, bied unieke en uitdagende geleenthede op die gebied van onderwys. Verskillende faktore beïnvloed, op die oomblik, die plaaslike onderwys scenario. Die koms van Kurrikulum 2000 en Uitkomsgebaseerde Onderwys het die deur vir toepaslike wetenskap- en tegnologie programme, as deel van skoolleerplanne, geopen. Die toevoeging van Tegnologie, as vakgebied, tot die junior sekondêre fase, skep die geleentheid om studente in aanraking te bring met, byvoorbeeld, die enorme wêreld van materiaalkunde. Senior sekondêre studente het egter min tot geen blootstelling aan materiaalkunde leerprogramme ten spyte van die feit dat hul lewens daagliks deur moderne materiale beïnvloed en beheer word! Daar bestaan 'n behoefte aan hoë kwaliteit, maklik bekombare inligting oor moderne materiale en vandaar die dryfveer om hierdie program te skep.

Afhangende van die standaard van die studente, kan hierdie program gebruik word as:

- 'n onderrigprogram vir onderwysers en lektore
- 'n bron van inligting wat studente interaktief kan navigeer om meer van polimeeerchemie te wete te kom

- 'n bron van inligting vir enigiemand wat nuuskierig is oor die interessante wêreld van plastieke.

Die naam van hierdie program: "Fun with Polymers" dui daarop dat die wetenskap-leerproses pret kan wees! Die program bestaan uit maklik navigeerbare instruksies, hulplêers, hiperteks, klank, animasies, en foto's om lig te werp op die onderwerp van plastiek. Die inhoud beslaan die geskiedenis van die ontwikkeling van plastiek= materiale, basiese polimeerchemie beginsels, inligting oor die vorming van makro= molekules, feite oor sintetiese polimeermateriale, en vrae en antwoorde om die gebruiker te toets oor sy/haar kennis. Maklik uitvoerbare en toepaslike praktiese eksperimente komplimenteer die teoretiese inhoud van die multimedia program.

Abstract

Multimedia was the buzzword of the previous decade. Electronic learning is the buzzword of this decade. Both concepts changed, and are still changing the way educators present knowledge and information to students, both locally and worldwide.

South Africa, also standing in the midst of these technological changes, has its own unique opportunities regarding the teaching environment. Different factors are currently changing the educational scene in South Africa. With Curriculum 2000 and the Outcome-Based Education concept (OBE) came the opportunity to choose and incorporate relevant science and technology programmes into school curriculums. The introduction of Technology as a subject in junior secondary school, opened the door to bring students in contact with, for example, the vast world of material science. Senior secondary students, on the contrary, have little or no exposure to teaching programmes on modern materials; materials that rule their lives! There is a need for high quality, easily accessible and informative material science programmes. This provided the initiative to create this programme.

Depending on the standard of students, "Fun with Polymers" can be used as:

- a lecturing tool for teachers and lecturers
- an encyclopeadia which students can interactively navigate to learn more about polymer science

- a source of information to anyone curious about the interesting world of plastic materials.

The name “Fun with Polymers” indicates that learning science can be fun (after all!). The programme contains easy to use navigation buttons, help-files, hypertext, sound, animations and pictures to teach synthetic polymer material science. Content consists of the history of the development of polymer materials, basic polymer chemistry principles, information on the building of macromolecules, facts on synthetic polymer materials, and some questions and answers to test the student’s knowledge. Practical experiments, with plastic materials, complement the theoretical information and provide students with hands-on experience.

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Introduction

"The world looks so different after learning science.
Trees are made of air, primarily,
and when they are burned, they go back to air.
In their flaming heat is released the flaming heat of the sun
which was bound in to convert the air into a tree.
In the ash is the small remnant
of the part which did not come from air,
that came from the solid earth, instead.
These are beautiful things, bursting with the unraveling
mystery of science,
inspiring man to continue on an eternal discovery."

Richard Feymann

In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone. Everyone needs to use scientific information to make intelligent choices that arise daily. Everyone needs to be able to engage intelligently in public discourse and debate important issues that involve science and technology. Everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world. More and more jobs demand advanced skills, requiring that people be able to learn, reason and think creatively, make decisions and solve problems. An understanding of science and the processes of science contribute in an essential way to these skills.

Environmental goals have led to new standards and the priorities of the world have shifted from military to economic security. Our environment is ruled by the science of materials. Progress in material science has stimulated the economy of the world and has a great influence on living standards of our society.[1] Materials that have been used over the millenniums have so profoundly influenced human civilisation that distinct time periods have been defined by the names of materials dominant during an era: the Stone Age, the Bronze Age and the Iron Age. The 20th century was no exception to this rule, therefore Giulio Natta, winner of the Nobel prize for Chemistry in 1953, called it: "the Age of Plastics"[2].

For centuries, naturally occurring raw materials like wood, cotton, leather, wool, natural rubber and glass were principal ingredients of simple technological innovations. At the dawn of the 20th century these materials were still the dominant resources of the world economy. From the middle of the 1900s this dominance was increasingly overwhelmed by the development of modern materials like: plastics, steel, ceramics, semi-conductors, composites, concrete, synthetic rubbers, super-conductors[3].

Over centuries we have shaped materials to suit our needs, which include:

- instruments to gather and prepare food
- shelter to protect precious property and human lives
- clothes to wear
- weapons to make war or to protect ourselves.

Nowadays we use modern materials to:

- launch a space ship
- dive under the sea
- improve the eyesight of a near blind person
- transplant an artificial heart
- package and deliver fresh food and drinks
- build a car, aeroplane or home

- store precious information on chips as big as a fingernail!

From the moment we wake up in the morning, until the moment we go to sleep at night, we actually touch and use hundreds of different modern materials.

The shaping of these modern materials involves many steps: extraction of the raw material, conversion of the raw material into a desired material and then the final shaping. Choosing the correct material is often a critical part in the design of a product. Chemical composition, thermal behaviour and mechanical response of the selected material, are all variables that influence the design of a product and by altering any of these conditions, the characteristics can be changed completely. In order to develop the most successful products, scientists and engineers must understand the materials they use to build their products. Ignoring even a single design factor can mean the difference between success and failure. These materials are in different formations, on a variety of places and have different applications in our current industry.

Two major questions appear:

- in the light of what has been mentioned in the previous paragraphs, can we afford to neglect the teaching of modern materials as early as secondary school level?
- are current pollution issues not related to the unawareness of basic knowledge of the materials we use and dispose of every day of our lives?

Until 1995 the teaching of modern materials did not exist in South African schools. With the exception of basic information on metals, primary and secondary school pupils have little or no exposure to the following:

- synthetic polymers (encompassing the vast range of modern plastic materials)
- structural materials (concrete, ceramics, engineering plastics, composites,)
- functional materials (memory alloys, piezo-electric materials, pyro-electric materials)
- multifunctional materials (thermo-eletrostrictive and thermo-magnetostrictive materials)
- smart or intelligent materials (materials sensing changes in the environment, integrating sensed information, making judgements and reacting because of stimuli)[4].

Children use these materials every day of their lives, but they are not educated to understand the basic chemistry, behaviour and properties of these materials. There is certainly no exposure to future developments in material science. The only education in material science starts at tertiary level, most of the time as a post graduate course!

The program on polymer science, developed during this study, was created to fill the need for relevant theoretical and practical knowledge about synthetic polymer materials on secondary school level (see chapters 5 and 6). Synthetic polymer science is only one area of modern material science not covered in current school curriculums.

The impact of an ever-changing world of science around us demands that we search for and review new and more effective ways of bringing the world of science to all learners. More importantly, that we must implement these ways of teaching. Science on a blackboard is a sure way to stifle enthusiasm, relevant questioning and inquisitiveness of the world around us.

(Throughout this programme the term "polymer" refers to synthetic polymers. The term "plastics" is often used as a synonym for synthetic polymers.)

Chapter 1

Motivation and Objectives

1.1 Motivation for the project

Prospective and practicing science teachers are the representatives of the scientific community in their classrooms. They acquire and form much of their image of science through the science courses that they took at tertiary level education and the way it was taught to them at school. If this image of science is not in the form of a process of continual learning through inquiry, with opportunities to use scientific literature, media, and new technology to broaden their knowledge beyond the scope of immediate inquiries, science in the lecture hall and/or classroom is dead.

Effective science teaching is more than knowing scientific content and some teaching strategies. A skilled teacher of science requires not only knowledge about science, learning, pedagogy and students, but also how to apply this knowledge to science teaching. Teaching science should be a learning experience for the teacher too. It should:

- integrate all pertinent aspects of science, especially modern science, and science education
- focus on real situations and be presented in a variety of places where effective scientific teaching can be demonstrated
- provide continuous opportunities for inquiry into science phenomena[1].

One of the major problems, facing a science teacher, is that a subject like polymer science is a specialised field and just to try teaching polymer science, without proper knowledge, can be a daunting task. The introduction of Outcome-Based Education in South African schools creates the opportunity to incorporate courses on relevant and interesting subject matter, like polymer science, to broaden the knowledge of both teachers and students. Obstacles to the integration of polymer science concepts into the existing curricula are:

- the lack of polymer-related material **textbooks** and other relevant **resources**
- lack of **time** to gather and adequately prepare this specialised information for presentation to students to enjoy and have a learning experience
- non-availability of **apparatus and chemicals** to get hands-on experience of plastic materials
- little or no **financial support** to implement such programmes.

Motivation for the development of a relevant polymer science programme includes: the introduction of outcome-based education to schools, the use of technology to enhance student learning and the absence of any functional plastic material science programme in the local school system.

1.1.1 Outcome-Based Education

Massive technological, economical and social changes, challenge us to upgrade standards on all levels of education. The education sector will hardly receive more financial support or better resources for quality education, and still the challenge will be to be more responsive and effective. The importance of a system that teaches skills instead of content from a textbook requires an entirely new approach to learning. This is the main driving force behind the restructuring of education on all levels of our society:

".......the need to change from contents based education to out-come based education."

What is Outcome-Based Education? It means to clearly focus and organise everything in an educational system around what is essential for all students to be able to do successfully at the end of their learning experience. The key concepts here are:

- developing a clear set of learning outcomes around which all of the system's components can be focused
- establishing the conditions and opportunities within the system that enable and encourage all students to achieve those essential outcomes.

What are these outcomes? Outcomes are not values, beliefs, attitudes or psychological states of mind. Instead outcomes are what learners can actually do with what they know and have learned – tangible application of what has been learned. This means that outcomes are actions and performances that embody and reflect learner competence in using content, information, ideas, and tools successfully [5].

How does an interactive multimedia programme like "Fun with Polymers" contribute to effective science teaching?

Moving from teacher-centric education to learner-centric education makes the learner responsible for his/her own learning and the learning experience more relevant. The motivation for "Fun with Polymers" is to be **learner-centric.** The teacher or educator is merely the facilitator of learning on the topic of synthetic polymer materials. Learning is relevant to real life situations, according to the experience of the learner, and he/she should be able to apply this knowledge effectively every day.

The **teaching style (methodology)** of the programme is to stimulate the learner to critical thinking, reasoning and research. The learner can engage in debate over synthetic polymer materials and start to experiment with these materials in a practical programme. The learner is able to work at his/her own pace.

Contact with **new learning material** encourages an eclectic approach by taking into account a wide range of resources. Some of the **general outcomes** emerging from this programme should be to use this new science information in showing responsibility towards the environment and health of others. Another is that it demonstrates an understanding of the world as a set of related systems by recognising that problems around synthetic polymer materials do not exist in isolation, but in relation to our environment. It also promotes to new educational, career and entrepreneurial opportunities.

Specific outcomes of this programme are as follows:

- the use of process skills to investigate phenomena related to synthetic polymer materials

- to demonstrate an understanding of concepts, principles, and acquired knowledge of synthetic polymer materials
- to demonstrate an understanding of how knowledge about plastic materials contribute to the management, development and utilisation of natural and other resources
- the use of knowledge of plastic materials, through experimenting with raw materials, to support responsible decision-making in designing of products
- to demonstrate knowledge and understanding of the relationship between synthetic polymer materials and culture
- to demonstrate an understanding of the interaction between polymer science and socio-economic development.

1.1.2 The use of technology to enhance student learning

There is no question that technology is at the forefront of educational reform and that concepts like: "electronic learning", "computer based training" or "the cyber school" either from a CD-ROM or the INTERNET are concepts of much recent debate and discussion.

If technology is implemented in an educational system, it is important that it is designed to be a "tool" in the hands of educators and students and be vitally linked to the curriculum. Often technology is viewed as a curriculum unto itself rather than a curricular tool, much the same as paper and pencils are tools in the hands of students. Students should not only be involved in closed-ended tutorial or reading programmes but also take part in open-ended approaches using technology to construct meaning with curriculums that leads to effective outcome-based education[6].

There is, however, a rising concern that spending large amounts of money on technology will not guarantee improved student achievement. Policymakers and the public are now starting to demand evidence from schools that their investments in educational technology are worth the money. Reports conducted on the effectiveness of technology in the classroom reflect mixed findings [7].

In a groundbreaking study on the effectiveness of technology with six and eight graders, Harold Wenglinsky (1998) showed that computers raise student achievement and even improve a school's climate. However, computers have to be placed in the right hands and used in the right ways. If used for wrong purposes, computers appear to do more harm than good[8].

Educators need to know and understand that for technology to be used as a tool, the curriculum must be organised around concept-based instruction. When the curriculum is organised by concepts, learning activities are integrated, as they are in life, so that students use skills and processes for constructing meaning and solving problems. Because the use of technology is integrated by nature, in that any use of a computer involves multiple tasks, technology is a perfect fit for concept-based education[6]. This does not compromise the teaching of basic skills, in this case: basic chemical principles. Instead it extends those basic skills to meaningful applications, like the application of plastic materials, to encourage broader thinking and independent learning, paralleling the demands of the workplace.

The introduction of an interactive polymer science programme on compact disk brings not only change but also risk to the educator. Even with adequate training, teachers find technology, and not necessarily the content of the programme, threatening, at the very least. This is especially the case for teachers who are resistant to change, who fear failing at something new, or who are overwhelmed by the responsibilities and outcomes of such a subject.

For example, if a teacher is supposed to use a computer for instruction, the chances are that he/she will often ignore using them with students because it is too difficult or requires too much time and risk. A critical prerequisite for successfully implementing an interactive computer programme is to target staff and a school community where positive aspects of technology change are nurtured[6]. This approach was followed in the evaluation of both the multimedia and the practical programmes.

"Fun with Polymers" is a programme where the teacher may use the compact disk as a source of information in lecturing polymer science. Or, the student can be motivated to do his/her own research. (Students are most of the time more able to use technology than we give them credit for!) The acquired knowledge is then strengthened by hands-on practical experiments.

The use of the INTERNET to enhance student learning is most certainly the subject of much recent and controversial discussion. According to recent articles, research about the effective use of the INTERNET, as a technological tool, in scientific classroom activities, is at a very early stage. Studies still differ on: how do students interpret science information, carry out any assignments and go about finding and using science information from the INTERNET.

Research at schools using the INTERNET to explore assignments on science-related sites, showed the following results:

- Students' modification and interpretation of the task diverted them from the goal of engaging with relevant science content. They pursued goals entirely different from those the teacher intended while creating the expected product
- Students regularly interpret tasks in ways that make them less complex and demanding, reducing them to "schoolwork" – tasks that in essence merely fill up the school day
- Finding and using the correct information from diverse resources is a complex task, involving higher order skills of evaluation and synthesis not connected to the knowledge of a science topic itself
- Student interpretations and simplifications of the task of finding a single source that might provide an answer (that is, the source rather than the answer becomes the goal), or accepting information from any source at face value without evaluation or synthesis[9].

Secondary school education in South Africa still has a far way to go to create an environment where the INTERNET is incorporated in the classroom. According to media reports Educational Departments of the different provinces in South Africa, view the INTERNET as an invaluable tool for future education. They are constantly on the lookout for viable opportunities to bridge the gap between institutions with access to the INTERNET and those without it. Projects to provide schools with basic computer hardware and software and further upgrading to be connected to the INTERNET, are backed by continual training of teachers and providing essential information[10].

Nevertheless, the World Wide Web in particular has become a virtual boomtown for online education, with teachers, administrators and parents eager to gain access to this seemingly boundless resource. We can only gain valuable information from those who already has walked the way!

1.1.3 Relevant programmes

The science curriculum in South Africa contains little to no information on plastic materials for secondary school students. A chapter on Organic Chemistry, in the final year science curriculum, includes only a maximum of five pages on both petrochemicals and polymer science[11,12]. Until 1995, an option to do an industrial project on SASOL chemical processes, was mentioned in the senior syllabus but omitted after 1995. This year also sees the introduction of Technology as a subject in the junior secondary phase (Grades 7,8 and 9) where students are in contact with a broader spectrum of materials, but no polymer science.

The Plastics Federation of South Africa printed a booklet on plastics in 1990 called "Teachers Workshop" [13]. Information covers basic polymer chemistry, plastics processing/ manufacturing and environmental issues and is aimed at Grade 5 to 7 students. Enthusiasm for this programme faded because of a lack of financial support and no marketing. Occasional invitations of regional training consultants of the Plastics Federation are the only exposure of secondary school students to the plastic industry. Presentations consists of video material on processing and manufacturing of plastic materials and environmental issues, without any information on polymer chemistry or hands-on practical activities.

A selection of modern materials- and polymer science programmes, presented in different countries, are listed.

- In the **United Kingdom** the awarding body OCR (Oxford Cambridge and RSA examinations) runs a chemistry programme in the Nuffield GSCE syllabus which are complemented by publications based on the Nuffield approach. The topics, in this beautifully illustrated course, are chosen because they both have an intrinsic interest and are concerned with important aspects of chemistry and the applications of chemistry in society. Chapters on petrochemicals and polymers are packed with relevant information and linked to a programme of practical work. Practical activities and worksheets help the students to learn from the text and to use skills to carry out investigations[14].

- The MATTER *Initiative for Schools* is a project on CD-ROM of The University of Liverpool, **United Kingdom** supported by the European Social Fund. This interactive CD-ROM is designed to help students (primary school level) with a number of important materials-related concepts in the national curriculum for science. Topics on polymer science and plastic materials are not yet available. The CD contains details of further resources to support the teaching of materials science. The advanced CD-ROM for higher education covers the areas of modern materials and is packed with interactivity, animations and thought-provoking questions and tasks[15]. Although the level of presentation is to advanced for secondary school students, some information on modern materials can still be used for teaching and research.

- The University of Southern Mississippi in the **United States**, Department of Polymer Science has a popular polymer science programme, Macrogalleria, available on CD-ROM and the Internet[16]. The mission of this project is to provide working knowledge of polymers and related concepts to students of all levels, from K-12 to graduate-level and the general public as well, and to do so on multiple levels, so that the programme will be both informative and entertaining to both beginners and more advanced students of polymer science. This programme aims not only to provide an introduction to polymer science for those pursuing scientific careers, but to provide information in such a way that will interest the non-scientist as well, to the end of helping to create a more scientifically literate general public. Although parts of this advanced programme are suitable for secondary schools, lengthy information has to be scrolled down and the interactivity strength of the multimedia platform is partly lost.

- A Materials Science and Technology Teacher's Workshop prepared by University of Illinois, Urbana/Champaign, **United States**, is partly available on the INTERNET and as a textbook in quality format[17].

These modules are intended to introduce both teacher and student to the world of materials science and technology. There are eight modules including a module on polymer science. The other seven modules cover ceramics, metals, polymers, semiconductors, composites, concrete and energy. Scrolling text without any multimedia enhancements present the student with advanced information on polymer science. The practical activities targets Grade 10 to 12 students and fits into the science curriculum laid down by their National Science Foundation.

- The Center for Chemical Education (CCE), Miami University in Ohio, **United States**, houses Terrific Science Press and its publications. Their materials, including publications on polymer science and practical activities, are classroom-tested by teachers working with students at the targeted grade levels. These courses have reach thousands of teachers and students since 1987 and include practical activities in line with the local science curriculums.

- The National Plastics Center and Museum, Massachusetts, **United States**, is a non-profit institution dedicated to preserving the past, addressing the present and promoting the future of plastics through public education and awareness. This mission is fulfilled by organised tours and lectures in the museum, and hands-on science programming for schools, organisations and the plastics industry since 1995.

- The Environment and Plastic Industry Council under The Canadian Plastics Industry Association, **Canada**, is an industrial organisation designed to deliver core services and value to members of the Canadian plastics community. Its educational activities include an interactive web site detective game for children; a teacher's resource kit on-line; teacher and student newsletters; educational displays and tours and community outreach programmes.

- The online polymer science programme designed by the Key Centre for Polymer Colloids, University of Sydney, **Australia**, is established and supported by the Australian Research Council's Research Centre's Program. This programme includes advanced polymer chemistry and general information about plastic materials also useful to secondary school level. School students and teachers interested in polymer science are catered for by presenting summer school workshops and practical activities.

1.2 Objectives

The first objective of the work presented in this thesis is to create an interactive multimedia programme on synthetic polymer materials to assist in fulfilling the following targets:

- to **provide accurate and adequate information** on synthetic polymer materials.
- to **provide correct answers** on frequently asked questions about synthetic polymer materials:
  Where do they come from?
  What is it made of?
  Where is it used?
  Can it be recycled?
  Is it detrimental to our health and the environment?
- to **stimulate the learner** to be involved in the vast world of modern materials

- to **contribute to effective teaching** by providing the teacher with correct and relevant resources on synthetic polymers
- to **save time** for both teacher and student in the search for relevant knowledge.

The second objective is to create practical programmes on primary and secondary school level to meet the following needs:

- to **provide the necessary chemicals and apparatus** to perform basic plastic experiments
- to **provide correct procedures** to perform basic plastic experiments under local educational circumstances
- to **contribute to effective teaching** by providing the teacher with correct and relevant information to link experiments to our environment and daily use
- to **stimulate students to learn** how to create, use, re-use and correctly dispose of plastic materials by hands-on activities.

Furthermore, the growing need for plastic manufacturers to assume a higher profile in addressing environmental issues is becoming more important. This is due to the upsurge in public interest, increasing controversial attention by the media and the sudden earnest interest of the Government in using, re-using and misusing of plastic materials.

Blame for plastic pollution should not be cast on the plastic material itself but the ignorance of people using plastic articles and the inefficient disposal of it

after it has served its primary purpose.

Plastic materials are effective, economic, versatile, time- and energy saving, clean and stable and constitute a large percentage of articles essential to our modern lives. There is an increasing need for effective and early education in the field of plastics to create enlightened attitudes throughout all levels of society. This programme strives to contribute to this need.

Chapter 2

Science and Multimedia

People retain only 20% of what they see

and 30% of what they hear.

But they remember 50% of what they see and hear,

and as much as 80% of what they see, hear and do simultaneously.

-Computer Technology Research, 1993[11]

Pierre –Gilles de Gennes, Nobel Laureate in Physics, 1991, wrote: In rural France of yesteryear, children used to be in daily contact with nature and with the world of craftsmen, which gave them a sense of observation and manual work. Today, access to computer technology is a necessity, but if we are content to sit our young people in front of computer monitors (which they love) [to learn about science], we are at risk of losing something precious. To form a generation that knows only how to hit a keyboard to produce results is a scary prospect! [12]

The previous century came to a close with the generic term “interactive multimedia” being the buzzword around us. Multimedia is fast emerging as a basic skill that will be as important to life in the twenty-first century as reading is now. The impact of multimedia on education is likely to be the most controversial of all technological advances in this new century. It is changing the nature of reading itself, because text is being brought alive by sound, pictures, music and video. Anyone who plans to learn, teach, work, play, govern, serve, buy or sell in the information society needs to know about multimedia.

Multimedia technology, which combines video, sound, pictures, animation and text, has afforded the production of a wide variety of educational applications in many disciplines. It is a costly and time-consuming process. It involves many programming hours and also extensive material writing by a subject expert to satisfy the large storage capacity of CD-Rom. Multimedia programmes therefore have an extremely high "learning-material-to-production-time" ratio. The costs of producing multimedia materials are likely to escalate as new material-hungry, technologies, such as Digital Video Disc, begin to appear.[13]

Questions on multimedia and science that arise are:

- Can multimedia be used as an effective tool to enhance the understanding of science?
- Is multimedia a substitute for classroom science teaching or lecturing?
- Is the use of multimedia technology not a deviation from the real life experiencing of science?
- Can multimedia assist in laboratory experimental work and how?
- Can multimedia bridge the separation between textbook and practice?

Multimedia, in this presentation, is defined as the use of a computer to present and combine text, graphics, audio and animations with links that let the user navigate, interact, create and communicate. It is based on the fact that there must be:

- a computer to interact with and to co-ordinate what you see and hear

- pathways that allow you to follow your own way of thinking and traverse the web of connected information
- ways to gather, process and communicate your own information and ideas.

The world of materials science is about touching, seeing and using materials in the environment. Using multimedia is not the beginning and the end of this scientific knowledge about materials. Nothing can substitute for practical experience in nature or performance in a laboratory. But, the simulation of a specific experiment, chemical reaction or manufacturing process, contributes to better understanding of how science rules the world we live in. The use of multimedia enhances the science experience by creating visual interaction with materials and processes far beyond the pages of any book or classroom. Correct simulation and animation bring alive the subject of chemistry, one that teachers often find difficult to explain or demonstrate to students. Instead of limiting the student to a linear presentation of scientific information in books, multimedia makes reading dynamic by giving words an important new dimension. Words serve as triggers to expand the text in order to learn more about a chosen topic. Students have the opportunity to explore, prepare and review scientific information with very little effort.

The multimedia programme "Fun with Polymers" uses multimedia technology to present the world of synthetic polymer materials to the learner and orientate him/her in a world ruled by modern materials.

Why is information presented as a multimedia programme, preferable to the same information presented as text in a textbook?

- Movement of text focuses the reader on important information
- Text accompanied by animations enhances the visual learning experience of the user
- The user has control to move from screen to screen using predetermined links
- Hypertext allows the concept of non-linear text. The user has access to further knowledge (sometimes at a deeper level)
- Restriction of the computer window forces the designer to present only relevant information, leaving the user to make choices to access further knowledge – the way research is done!
- The main outlay of the programme, soft buttons with access to help files, previous menus or more information are immediately available at the click of a button
- Use of background images puts the user in an environment related to the subject matter – in this case polymer science
- Colour schemes give dynamic changes between different screens
- Flow diagrams present information about industrial plants and chemical reactions in sequential ways
- Animations demonstrate chemical reactions in such a way as to create a visual reaction to the user
- Links can be binary, hierarchical or of a network configuration.

Educating the student of tomorrow requires a new education belief – one that recognises that demographics are changing and that old ways of teaching will not necessarily work well in the future. It is not a question of how you can get the modern student to be like the student of yesterday, but rather how you can get the education environment to fit the modern student. Both classroom and textbook are limited environments; science curriculums must extend beyond these restrictions.

Chapter 3

Technical Aspects

3.1 Background to the project

The project started in January 1998 with computer software support from the Institute for Polymer Science, Stellenbosch University. The initial purpose of the project was to create an interactive multimedia programme for secondary schools in Southern Africa on the subject: Polymer Science. The target group was to be Grade 10 and 11 students at secondary school level, although any creative student in Grade 9, and persons without any knowledge about the world of plastic material science, can learn something by navigating through the programme. The practical programmes (discussed in Chapter 6 and Chapter 7, par. 7.2) developed alongside the multimedia programme to enhance the theoretical content.

The application uses a range of multimedia possibilities afforded by the current multimedia platform, and the design is based on state-of-the-art computer hardware and software available. From a pedagogical point of view, the programme is designed as a free-standing, self-study, learning resource, usable by learners at the levels indicated, and as a lecturing tool for teachers or lecturers, if computer facilities (see paragraph 3.2) are available. The presence of relevant and authentic pictures, animations and text information, already used as lecturing material in different courses at the Institute for Polymer Science, Stellenbosch University and the Plastics Technology Department, Cape Town Technikon, is central to the multimedia programme.

The interactive learning procedure and the content focus is based on the author's understanding of learning and teaching science at secondary school level in South Africa, taking into account the current level of curriculums and science education of Grade 10 and 11 students. This new programme was not considered as a substitution for any part of current science curriculums. Rather, it was envisioned to strengthen the hands of teachers and lecturers in need of relevant teaching/lecturing science material. This is in line with the now considerable evidence that multimedia is an effective environment for science knowledge acquisition[24,25].

3.2 Hardware and Software

The programme runs on a multimedia platform, with the following specifications:

at least a Pentium 1 central processing unit

at least 32 Mb of RAM

colour monitor, 256 bit colour

sound is optional

120 MHz speed processor

100Mb memory available

dual speed CD-ROM

standard mouse and keyboard.

The platform used to create this programme was Macromedia's Authorware 4.0, a software programme designed to create other software programmes, known as '*authoring tools*' or '*development platforms*'.

While Authorware can be used to create individual sound, animations and graphic elements, its real strength lies in the coordination of these elements and information from a wide range of other programs;

- The programme consists of easy to use icons to programme a totally interactive multimedia unit;
- It has highly interactive, hypermedia reference titles;
- Authorware is a powerful tool to use on the INTERNET. Shockwave is a fully integrated component, and media can be gathered from anywhere on the INTERNET to be a source for all the Authorware elements;
- The user does not need Authorware to run the programme; the programmed material is packaged with its own executable files and can run as a stand-alone product;
- It delivers interactive pieces on both Windows and Macintosh platforms[26].

Other programmes used to create animations, scan pictures, draw graphics and import text were mainly:

- Microsoft® Word (text)
- Flash 5.0 (animations and graphics)
- Image Composer (pictures and graphics)
- Corel® Photo Paint 10 (pictures and graphics)
- Smart Draw 3.0 (chemical structures)
- Hewlett Packard Precision Scan (scanning of pictures)

The importance of the End-User Environment should be taken into account when creating a software programme of this kind. Creating a multimedia programme on a platform using state of the art technology that can only be utilised by users with the latest in computer technology is senseless. There is no point delivering Java-enhanced Web pages or audio- and video clips, for example, to users with equipment older than five years. It is always a bad idea to adopt leading edge technology just for the sake of technology. This product was designed on compact disc specifically to be delivered via a computer with CD-ROM and basic capabilities. The use of sound is limited to enhance important effects, pictures are saved as .jpg-files to minimize download time, animations are limited to only a few sequential steps and there are no voice- or video material.

3.3 Authenticity of Text, Pictures and Animations

The main text of the program originated from tertiary level study material used for the Honours course in Polymer Science at the Institute for Polymer Science at Stellenbosch University[21] as well as the National Diploma in Plastics Technology at Cape Technikon, Cape Town[22]. The standard of information was adapted to suit the needs of the science student at secondary school level. The Polymer Materials Handbook of the *Plastics Industry Training Board (PITB)* of South Africa[3] was used as main reference for information to create chapters like “Building of Macromolecules” and “Synthetic Plastic Materials”[22]. The *Chemistry* book of *Nuffield Co-ordinated Sciences* [23] was used for content on “Basic Polymer Chemistry”. Information presented in the chapter “Historical Timeline” literally came from all over the world – magazines (nationally and internationally) includes:
Time-magazine, National Geographic, New Scientist, The Science Teacher, Plastics SA, Plastics Europe, Scientific American, Rubber Magazine Southern Africa, Scientific American,

as well as information gathered from different plastic companies like: *LINPAC, Permoseal, Mono Containers, Bakke, LINPAC, Sasol Polymers, Du Pont, Amico, ICI, DOW Plastics, SA Silicones, CH Chemicals, AECI Vynide.*

Animations to demonstrate and enhance the multimedia experience were the creation of the author. Animations are part of the Authorware 4.0 platform – there is no need for downloading any software programmes or plug-ins to play animations.

Pictures were taken by the author himself or gathered over time, for teaching purposes, from brochures and information of different companies.

3.4 Comprehension tasks

The programme is designed to develop knowledge skills by providing meaningful basic information about plastic materials. This consists of:

- a **history**, leading to the plastics age;
- chronological data to show the development of modern materials and technology;
- **basic polymer chemistry** to understand the role of raw materials, carbon atoms and ethene molecules in the building of macromolecules
- animations to give an idea of the **building of macromolecules** through different chemical reactions
- the importance of understanding polymerisation and the processes that constitute the plastic industry

- **plastic materials** used every day, interesting facts, applications and advantages
- basic **questions and answers** applicable to the different chapters.

The focus point of the programme is to let the user play and browse through information that has never been available on this level before. Screen after screen of scrolling text is avoided. The user has to "see" the information, most of the time, on one window and then decide which option to take. Accessing information via 'hot spots' or 'hot text' becomes progressively more difficult and progress depends on the educational level of the user.

3.5 Scientific background needed

Following current science curriculums in South Africa, a Grade 10 student should already know the theory leading to the modern concept of matter:

- the periodic table and its elements
- atoms consisting of protons, electrons and neutrons
- spatial orientation of an atom or molecule
- orbitals and valency
- molecules produced from covalent or ionic bonds
- attraction and repulsion forces
- basic chemical reactions between atoms, ions and molecules
- energy involved in chemical reactions
- IUPAC conventional way of writing and reading chemistry "language".

New scientific concepts acquired during this programme, that builds on previous knowledge, are:

- monomers, polymers, macromolecules
- thermoplastics, thermosets and elastomers
- crude oil and coal made up of hydrocarbons
- distillation and cracking of macromolecules
- the alkane and alkene families of molecules
- trans- and cis-molecule structures
- stereochemistry
- addition polymerisation, condensation polymerisation, co-polymerisation, cross-linking and vulcanization
- chemistry of the following materials: polyethylene, poly(vinylchloride), polypropylene, polystyrene, rubber
- atacticity, syndiotacticity and isotacticity;
- the purpose of catalysts.

3.6 Computer Skills

Basic computer skills to run this multimedia programme apply. The user must possess the following skills:

- be able to use a keyboard and mouse
- if the programme is used as a stand alone compact disc, skills to use a CD-ROM
- be able to launch a programme from the CD-ROM
- follow instructions and select pathways by using a keyboard or mouse.

Chapter 4

Design

4.1 Introduction

The design of a program refers to the graphical user interface (GUI) of the programme: the arrangement and layout of the graphics, text and tools or buttons, the use of the computer screen and the 'friendliness' of the programme to the user in general.

The following criteria were important in the designing of this programme:

- Is the background and colour scheme used effectively and do they 'invite' the user to learn more?
- Does the user always know where in the programme he/she is?
- Are the main menu, submenus, topics and subtopics of the different screens clear and understandable?
- Is the screen optimally used?
- Is the exit button always available and can the user "exit" at any stage?
- Is it possible to move directly back to the Main Menu or any other chapter?
- Do the pictures and animations contribute to the effectiveness of the information to be studied?
- Is it easy to access the hypertext by using effective hyperlinks?
- Is the sound enhancing the learning process or is it irritating?
- Are there adequate on-screen instructions and are they understandable?

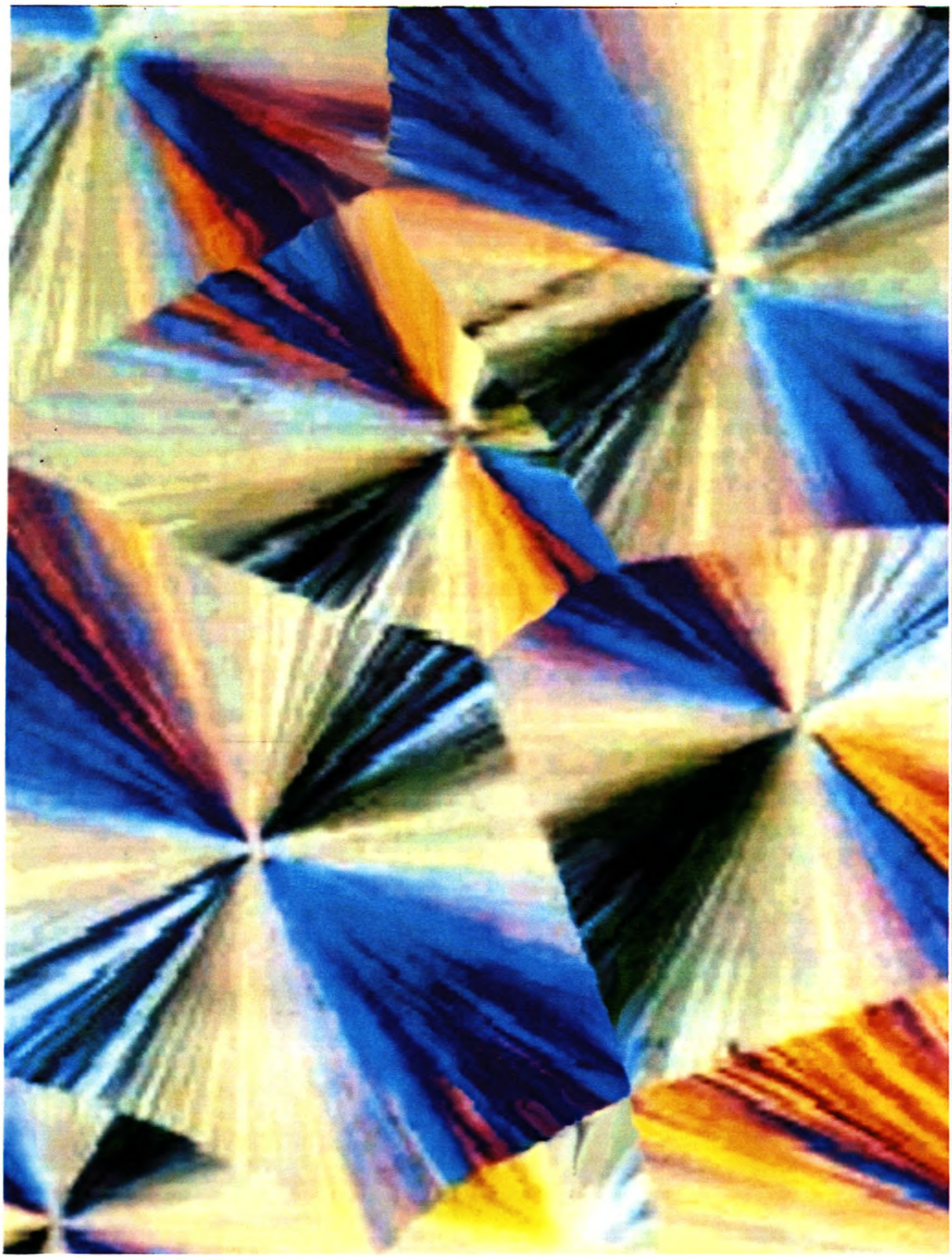
- Is there uniformity in the layout of the screens:

  are the buttons always the same, is the background a central theme, are topics uniformly positioned?
- Is the learning process sequential – from existing knowledge to new material?

4.2 Background of screens

The central theme of "Fun with Polymers" is to open a world of unknown knowledge and, maybe, unseen visuals to the user. As the background of all the screens, except the Help Files, is a picture taken at the Cape Technikon Plastic Technology Laboratory on 16 May 1999. A sample of High Density Polyethylene was melted and recrystallised to show clear plastic crystals (1 to 2 μm in diameter) formed by a slow cooling process. Magnified by a Nikon Light Microscope with magnification 400x, and photographed with a Pentax ME Super camera, Kodak 400 ASA film, shows the different spherulites of the HDPE material. Polarizers bring out the pyramidal form of the spherulites with different colours; the characteristic Maltese cross is clearly visible as well as the lamellae that have crystallised into the final product. (See picture on next page.)

Different variations of this theme were used to create the background of submenus and hypertext used throughout the programme.



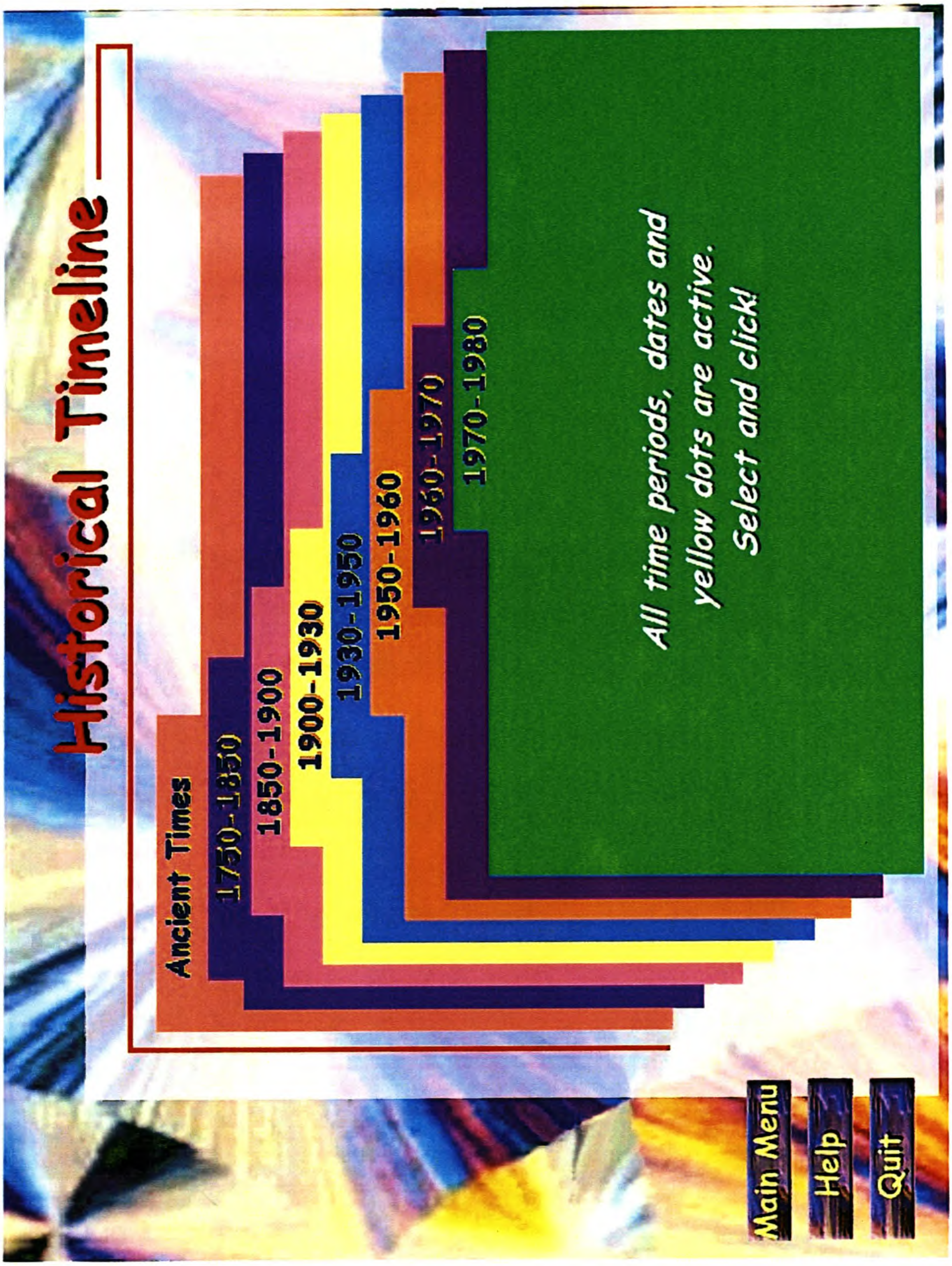
4.3 Opening screens

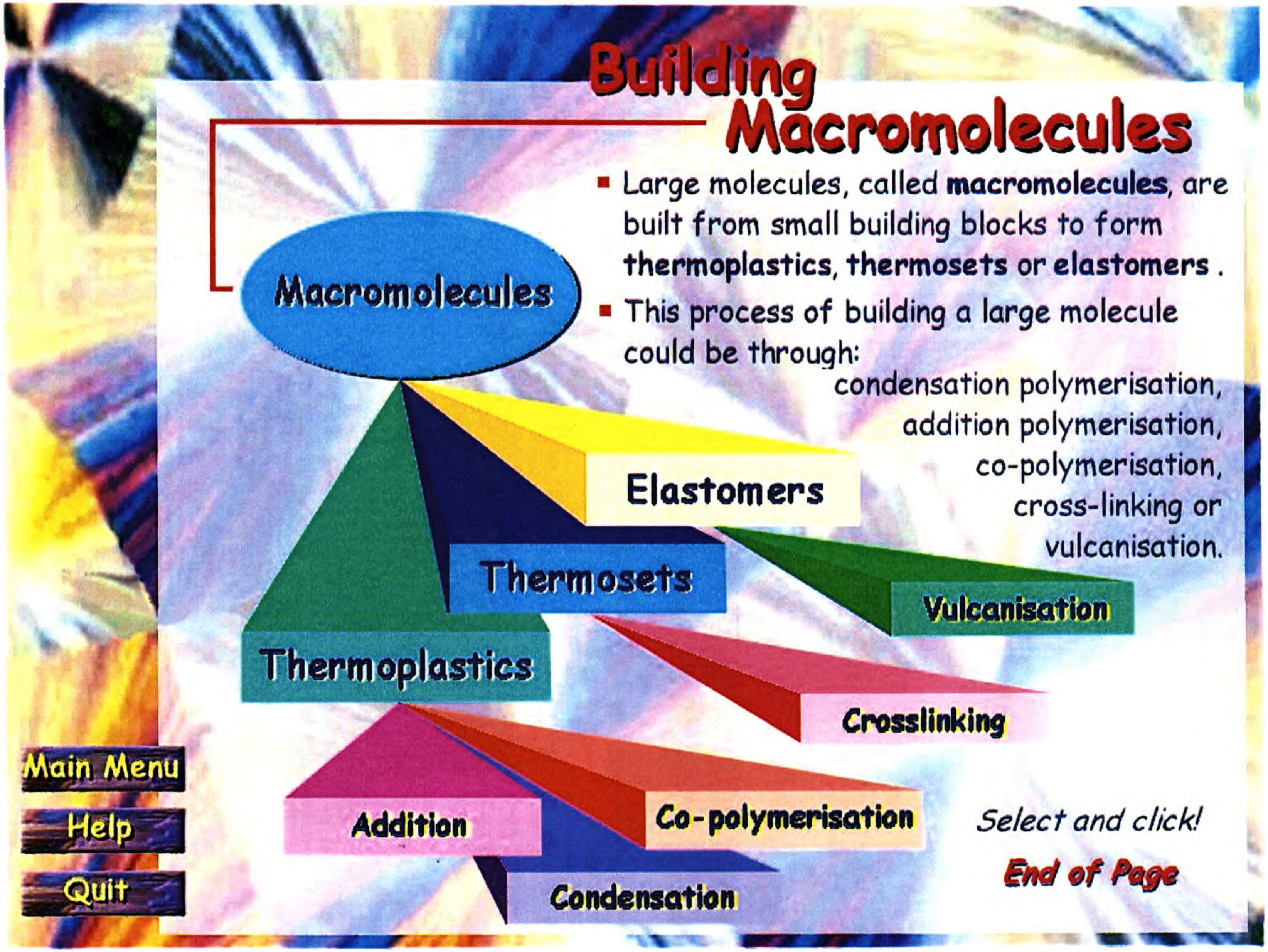
Although opening screens for each chapter were designed differently to keep the learning process and exciting experience, headings, buttons and text are constant throughout the whole programme.

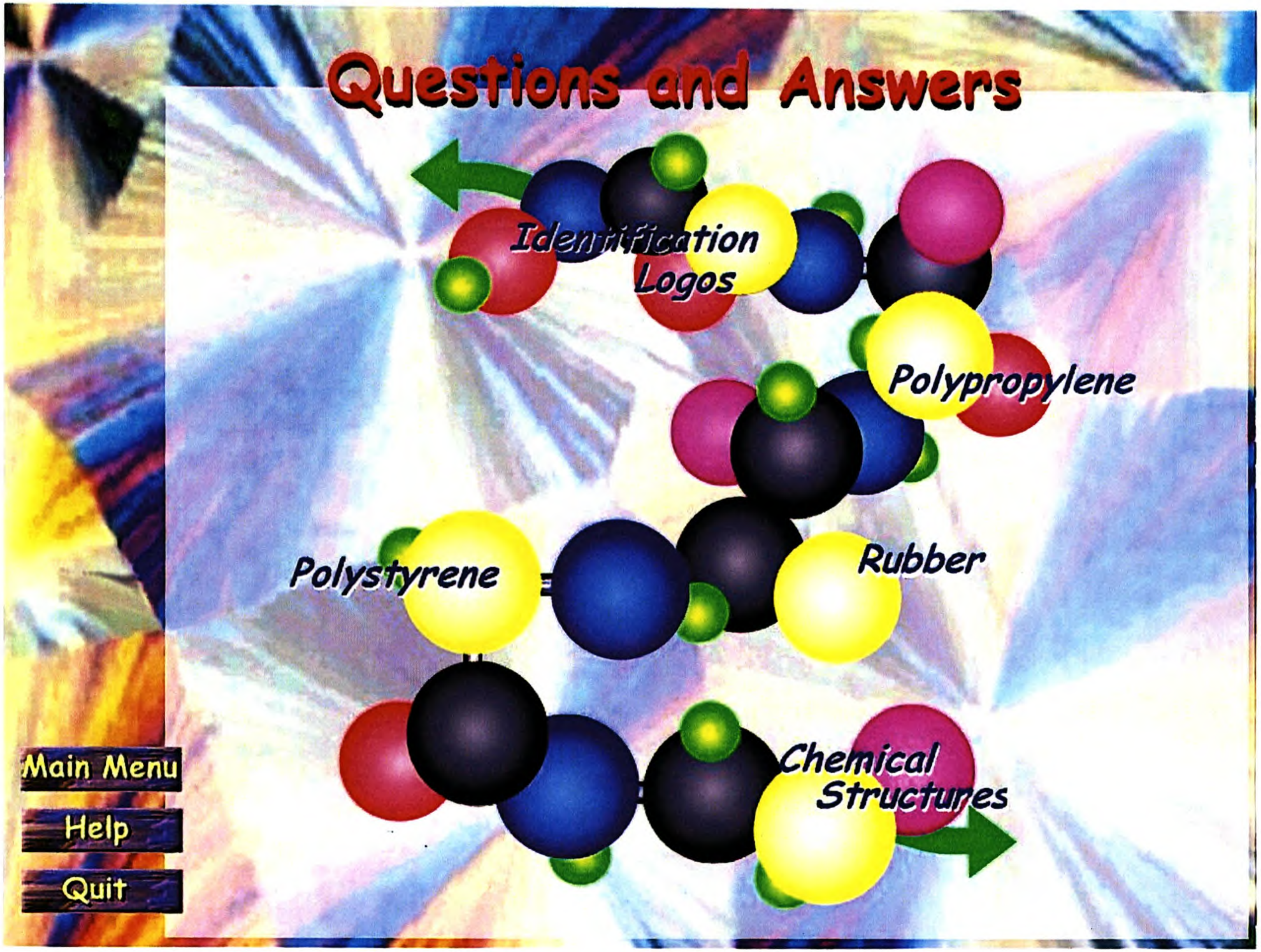
The screen on the history of polymer science, for example, uses flipcharts to present different time periods. A click on an active date will reveal information for that specific era. The opening screen of the chapter on building of macromolecules reveals the relation between thermoplastics, thermosets and elastomers [27]. These subjects link to animated modules on the building of giant molecules. The opening screen of the questions and answers section pictures a macromolecule with active atoms. A click on any atom will open a series of questions and answers on selected topics. (See pages 37,38 & 39)

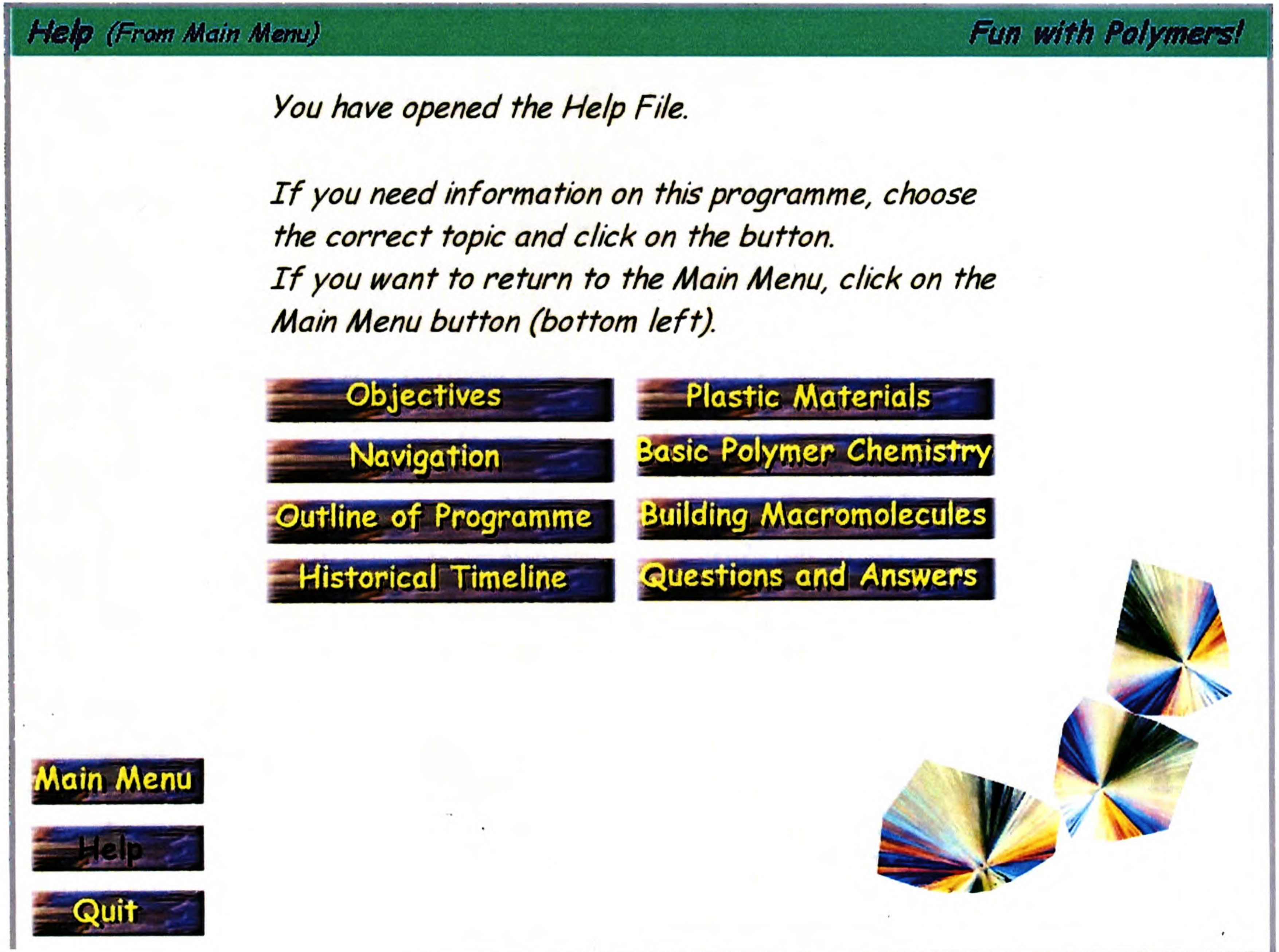
4.4 Headings

Headings, to indicate the six main chapters in the programme, are coloured red and positioned, throughout the programme, in the upper right corner of each window. These headings are always accentuated by a red underlined animation leading to the subheadings. Subheadings, indicating the different topics in a chapter, are coloured blue and always positioned in the upper left corner of each window. Headings are not active and no further information about a specific chapter or topic can be accessed via clicking on a heading. Information about a specific chapter or paragraph can be found in the help-files. (See page 40)


Historical Timeline
Ancient Times
1750-1850
1850-1900
1900-1930
1930-1950
1950-1960
1960-1970
1970-1980
All time periods, dates and
yellow dots are active.
Select and click!
Main Menu
Help
Quit


Building Macromolecules
Large molecules, called macromolecules, are built from small building blocks to form thermoplastics, thermosets or elastomers .
This process of building a large molecule could be through:
condensation polymerisation,
addition polymerisation,
co-polymerisation,
cross-linking or
vulcanisation.
Macromolecules
Elastomers
Thermosets
Thermoplastics
Vulcanisation
Crosslinking
Addition
Co-polymerisation
Condensation
Main Menu
Help
Quit
Select and click!
End of Page


Questions and Answers
Identification
Logos
Polypropylene
Polystyrene
Rubber
Chemical
Structures
Main Menu
Help
Quit


Help (From Main Menu)
Fun with Polymers!
You have opened the Help File.
If you need information on this programme, choose the correct topic and click on the button.
If you want to return to the Main Menu, click on the Main Menu button (bottom left).
Objectives
Plastic Materials
Navigation
Basic Polymer Chemistry
Outline of Programme
Building Macromolecules
Historical Timeline
Questions and Answers
Main Menu
Help
Quit

4.5 Buttons

Navigation through the programme is certainly one of the most important aspects considered. Two sets of buttons are important to using this programme:

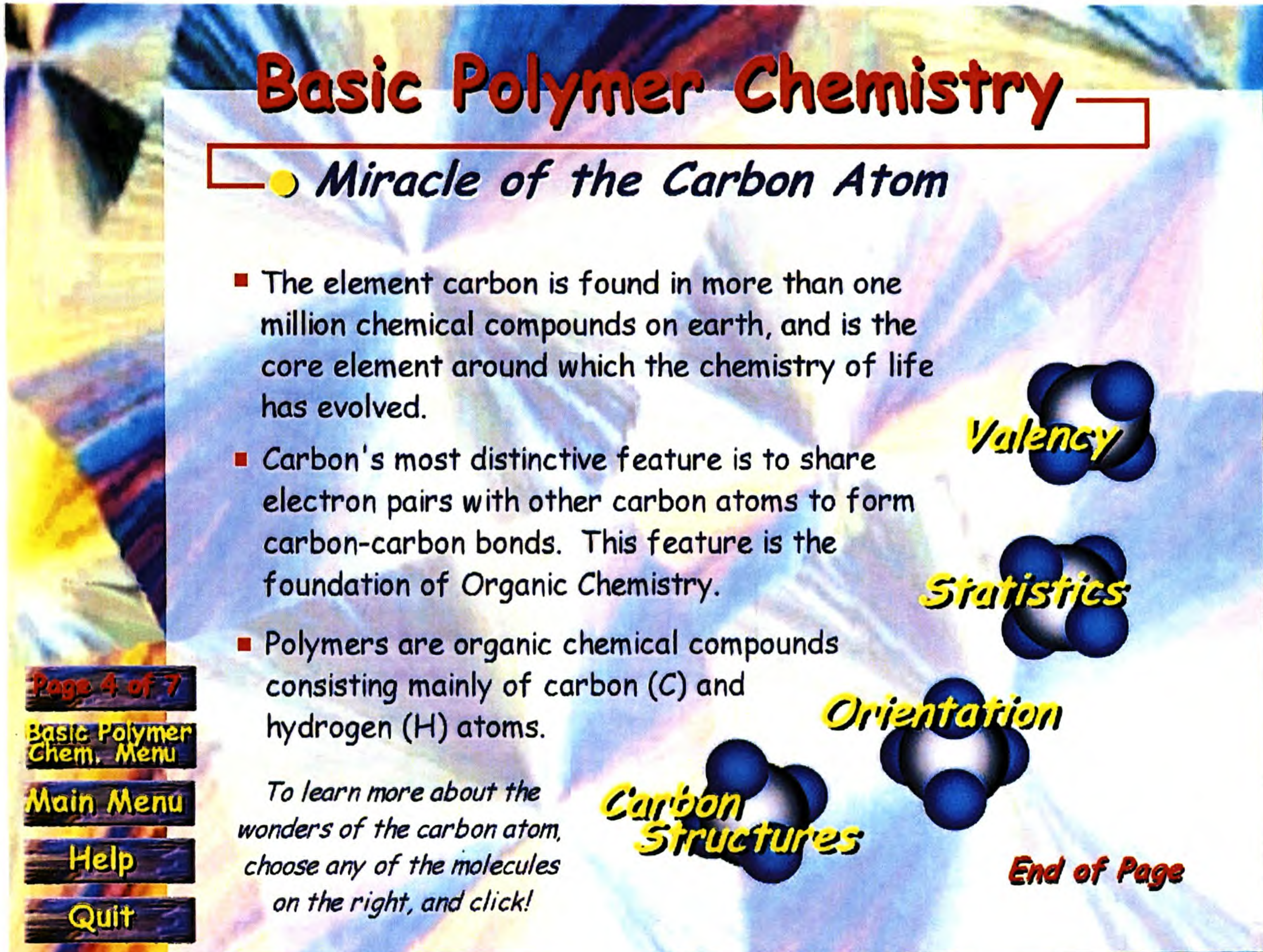
- Buttons used to navigate through the main structure of the programme that is: from chapter to chapter or screen to screen. These buttons are positioned in the lower left corner of each window and are perpetual.
- Buttons to navigate to animations, repeat animations or navigate to extra text, graphics or pictures. These buttons appear when information is accessed, and are not perpetual. Screens that open accordingly and leave the user with the choice to "Go Back", or a time limit is connected to the extra information or picture. (See page 42)

4.6 Text

Font used throughout the programme is Comic Sans. Font colour of the main text is prussian blue with font size 14 pixels. Font colours used in sketches, pictures and hypertext are black and white with font size 12 pixels.

Hypertext is always bold and/or yellow. Moving the cursor over an active button will change the cursor to a little hand and the text will move sideways or change to a yellow colour. (See p 42)

Apart from the Help Files, scrolling text is not an option. The design of this programme leaves the user with the choice to branch from a central window to other different windows, to go back (if necessary) or quit the window. It is important to wait


Basic Polymer Chemistry
Miracle of the Carbon Atom
The element carbon is found in more than one million chemical compounds on earth, and is the core element around which the chemistry of life has evolved.
Carbon's most distinctive feature is to share electron pairs with other carbon atoms to form carbon-carbon bonds. This feature is the foundation of Organic Chemistry.
Polymers are organic chemical compounds consisting mainly of carbon (C) and hydrogen (H) atoms.
To learn more about the wonders of the carbon atom, choose any of the molecules on the right, and click!
Valency
Statistics
Orientation
Carbon Structures
End of Page
Page 4 of 7
Basic Polymer Chem. Menu
Main Menu
Help
Quit

for the red "End of Page" indication before any hypertext, animations or hyper-pictures can be accessed.

4.7 Pictures and Animations

Text without any pictures or animations will only tell half the story of plastic materials. Pictures and animations are an integral part of this programme and closely related to the text and hypertext.

The flow of information on the screen includes pictures, emphasizing a text description or presenting additional visual information. Hypertext are often linked to pictures on a specific topic. In the section with information about the applications of synthetic polymer materials, pictures are active and are linked to text describing the importance of a product.

Animations appear on the screen as an integral part of a subject, flowing with the text. Animations are used to demonstrate chemical reactions or sequential stadiums in the formation of a final product. Replay buttons to review the animation are available after the appearance of the 'End of Page' button.

Chapter 5

Content of Multimedia Programme

5.1 Outline of the programme

Here follows an outline of the theoretical content used in the multimedia programme:

Historical Timeline:

Ancient Times
1700-1800
1800-1850
1850-1900
1900-1930
1930-1950
1950-1960
1960-1970
1970-1980
Modern Times

Basic Polymer Chemistry:

What is a polymer?
From raw materials to plastics
Classification of polymers
The wonder of the carbon atom
The alkane family
Alkanes to alkenes
The alkene family

Building Macromolecules:

Condensation polymerisation
Addition polymerisation
Co-polymerisation
Cross-linking
Vulcanisation

Plastic Materials

Polyethylene (HDPE and LDPE)
Polyvinyl chloride (PVC)
Polypropylene (PP)
Polystyrene (PS)
Rubber

Questions and Answers

Help Files

5.2 Information on the compact disk

The following section consists of the written text used in the multimedia programme. The dimensions of the computer screen restrict the use of elaborate text, especially if scrolling text is not considered as an option. Animations, pictures and graphics are simultaneously used to explain phenomena and cannot be represented here. Hypertext, that allows the user to access extra information, is given as additional paragraphs under specific headings.

5.2.1 Historical Timeline

Although plastic materials only came of age during the past century, the use of plastic materials was not always confined to our immediate forefathers. The Historical Timeline serves to show the user that certain plastic materials were already in use in ancient times and pictures a history of uses that made life easier and more bearable. History is divided in the Stone Age, Bronze Age, Iron Age and the fact that we can name the 20th century the Plastic Age is not far-fetched. No other material has influenced the very existence of mankind so dramatically as the development of plastic material in all its forms. Hardly any area of our lives and environment can be mentioned without being influenced directly or indirectly by the invention of a suitable plastic material. To see the importance of natural and synthetic polymers in context in our world, it is essential to know something about the history of these amazing materials and the development of synthetic polymer materials over the past century [27,28].

5.2.2 Basic Polymer Chemistry

Basic polymer chemistry starts from the point of view that the student has a basic knowledge of the atom theory, molecules, basic chemical reactions, basic chemistry structures and covalent and ionic bonding. The carbon atom is central to the understanding of the basic principles behind the macromolecular structure of plastic materials. The purpose of the program is to lead the user stepwise through the physical and chemical origins of plastic materials. Where do they come from, what are the building blocks, what are the unique characteristics and interesting facts about the materials and what are the advantages and applications.

On this level, information is divided into different sections that can be accessed via the Basic Polymer Chemistry main menu.

5.2.2.1 What is a Polymer?

- The term polymer is used to describe a very large molecule that is made up of many repeating smaller molecular units; 'poly' means many and 'mer' means unit.

- These small units are called monomers and are held together by chemical bonds we call covalent bonds.

The animation demonstrates the following:
monomer → one unit
dimer → two units
polymer → many units.

5.2.2.2 Classification of Polymers

- Polymers are divided into two classes: natural polymers and synthetic polymers.
- Natural polymers occur *naturally* in our environment and were the first polymers to be used making fabrics.
- Synthetic polymers are new, long-chain materials *synthesized* by joining together substances.
- Examples of natural polymers are:

  - carbohydrates like starch and the cellulose in cotton and wood;

  - animal proteins like wool or silk or proteins in the human body like hair, keratin in the skin and haemoglobin in blood;

  - rubber found in the bark of trees in Central America and Malaysia; rubber can also be a synthetic polymer material.
- Examples of synthetic polymers are...

  - plastic materials that can be either soft and remouldable thermoplastics or hard and rigid thermosets;

  - fibres manufactured from natural occurring fibre-forming polymers (rayon from cellulose) or from long chain polymers derived from oil and coal;

- rubber materials made synthetically (also called elastomers).

5.2.2.3 From Raw Materials to Useful Products

- The raw materials, oil and coal, consist of thousands of different combinations of hydrogen and carbon atoms called hydrocarbons.
- The more carbon atoms in a molecule, the heavier the hydrocarbon molecule is.
- The process of changing oil and coal into useful products is called refining.

The animation demonstrates a distillation process and final products manufactured from the raw materials.

5.2.2.4 Miracle of the carbon atom

- The element carbon is found in more than one million chemical compounds on earth, and is the core element around which the chemistry of life has evolved.
- Carbon's most distinctive feature is its ability to share electron pairs with other carbon atoms, to form carbon-carbon bonds. This feature is the foundation of Organic Chemistry.
- Polymers are organic chemical compounds consisting mainly of carbon (C) and hydrogen (H) atoms.

On this screen the user has four choices to access further information on the carbon atom:

- the chemical characteristics of the carbon atom;
- the electron structure of the carbon atom called the valency;
- the spatial orientation of the carbon atom and bonding possibilities
- its three distinct crystalline forms: diamond, graphite and fullerenes.

5.2.2.5 The Alkane Family

- Carbon atoms are capable of combining to form long chains. This results in the formation of hydro-carbon compounds.
- The alkane family is a group of hydro-carbon molecules which increase with one carbon and two hydrogen atoms, molecule by molecule.
- The general formula for the unbranched, single bonded alkane molecules, is: C_nH_{2n+2}.

The user chooses between:

- methane to butane: a basic animation to show the bonding of hydrogen and carbon atoms;
- pentane to octane: a basic animation to show addition of hydro-carbons to form heavier molecules;
- higher alkanes: information on the formation of waxy solids and pictures of applications in our lives.

5.2.2.6 Alkanes to Plastic

- Crude oil, natural gas or coal contains large hydrocarbon molecules called alkanes.
- These alkane molecules, also called naphtha fractions, are split into small gaseous unsaturated hydrocarbon segments, called: ethane molecules.
- The ethane molecules produced through this reaction are the building blocks of the plastic industry.
- The process by which naphtha fractions are split, is called: “cracking”

The animations demonstrate an alkane cracking process and the polymerisation of ethane.

5.2.2.7 The Alkene Family

- The alkene family is a group of hydro-carbon molecules with double bonds. We say the molecules are unsaturated because they contain fewer than the maximum number of hydrogen atoms and are called olefins.
- The general formula of the double bonded alkene molecules is C_nH_{2n}.
- Ethene molecules are capable of combining to form long chains. This results in the formation of long macromolecules called synthetic polymers.

The animation gives descriptive information on the different products obtained from the polymerisation of ethene.

5.2.3 Building Macromolecules

The theory behind building a macromolecule is essential to understand the formation and characteristics of plastic materials. Without basic knowledge about the processes to build macromolecules, no plastic industry is possible! These chemical processes are an enormous and ever expanding field of research and often accurate speculation! This program intends to provide the user with basic information regarding addition polymerisation, condensation polymerisation, co-polymerisation, crosslinking and vulcanization.

Synthetic polymer materials comprise thermoplastics, thermosets and elastomers.

- The thermoplastics form the largest group of polymeric materials. This group consists of the polyolefins (polyethylenes and polypropylenes), the polystyrenes and the polyvinylchlorides. The outstanding characteristic of a thermoplastic is that it can be softened by heating and will harden again on cooling. The process of softening and hardening can be repeated over and over again.
- Thermosets are characterised by the three-dimensional cross-linking of the macromolecules to give products that will not melt and that are largely insoluble once they have set. Urea-formaldehyde components and melamine cupboards and utensils are household names today.
- Elastomers (rubbery materials) are obtained from natural resources or from synthetic rubbers via cross-linking of the macromolecules. We call this process vulcanisation. They form an important group of materials because of their elastic recovery against great deformation over a wide temperature range.

Under the topic thermoplastics, addition polymerization, condensation polymerisation and co-polymerisation are discussed. Under the topic thermosets, cross-linking is discussed and under elastomers the process of vulcanization is discussed. All the chemical processes are accompanied by animated demonstrations.

5.2.3.1 Addition polymerisation

- The reaction starts with many molecules of the same composition, and a catalyst or initiator.
- The molecules must have double bonds to enable them to bond

- The polymerisation progresses in three stages:
  - Initiation: the catalyst breaks the double bonds allowing the molecules to link
  - Propagation: building of the macromolecule
  - Termination: the reaction stops.

5.2.3.2 Condensation polymerisation

- The reaction starts with two different groups of molecules.
- Each molecule has reactive atom groups at the ends.
- When these molecules combine, they give off a condensation product, which in most cases is a water molecule.

5.2.3.3 Co-polymerisation:

- For the process of co-polymerisation to start, at least two different groups of molecules are needed.
- The different molecules link to form:
  - co-polymers with alternating molecules;
  - block co-polymers where the molecules are in blocks or groups
  - graft co-polymers where the molecules are grafted onto the main chain.

5.2.3.4 Cross-linking:

- A polymer can have more than two reactive ends to react with other molecules or groups.

- Reaction between the different molecules results in a cross-linked network known as a thermoset.

5.2.3.5 Vulcanisation:

- Vulcanisation is a process to strengthen weak and soft materials for example: raw rubber.
- Amorphous rubber material consists of a bundle of giant molecules lying closely together.
- Sulphur is mostly used as a vulcanising agent to form chemical cross-links between the molecules
- Insertion of chemical cross-links between the giant molecules produces a strong network polymer.

5.2.4 Plastic Materials

Five plastic materials, we touch and use mostly throughout our lives, are chosen as subjects:

polyethylene both high density and low density
poly(vinyl chloride)
polypropylene
polystyrene
rubber

5.2.4.1 Polyethylene

What is ethene?

- Ethene is the final product of a process called cracking starting with an alkane molecule.

- The alkane molecule is heated with steam and broken down in ethene and a by-product.
- Ethene (or ethylene) is called the building block of the plastics industry.

What is polyethylene?

- Thousands of ethene molecules are heated under pressure with special catalysts.
- Ethene molecules join up to form a chain via their double bonds. Each chain may be up to 50 000 ethene molecules long.
- Polyethylene is supplied as small white granules.

The animation shows the growing of a polyethylene macromolecule.

Unique Characteristics

- Polyethylene consists of branched macromolecules produced mainly by two processes: low pressure polymerisation and high pressure polymerisation.
- From low pressure polymerisation we get high density polyethylene - a linear carbon-hydrogen chain with a small amount of branches
- From high pressure polymerisation we get low density polyethylene - a linear carbon-hydrogen chain with a high amount of branching.

Applications

- The freshness of your sandwiches at lunch is secured by polyethylene film used for food packaging.

- Strong and flexible laminating films provide waterproofing sheets and cover films used in the building industry.
- Crates for bottles, fresh produce, and waste to effectively handle food and waste, are used by the transport industry.
- Ice cubes, for a refreshing cold drink is probably from a polyethylene container in a refrigerator.
- A selection of heavy-duty flexible polyethylene bags makes it possible to safely pack and sell consumer goods.
- The agricultural industry uses drawn polyethylene fibre bags to distribute fertilizer for soil and highly nutritional feed for animals.

Each comment in this paragraph is accompanied by an appropriate visual example.

5.2.4.2 Poly(vinyl chloride)

What is vinylchloride?

- The vinyl chloride monomer structure originates from an alkene molecule as building block.
- The hydrogen atom, of the ethene molecule, is substituted by a chlorine atom giving the molecule its specific characteristics.
- The monomer from which poly(vinyl chloride) is made is vinyl chloride.
- Animation: from ethene to vinyl chloride

What is poly(vinyl chloride)?

- Through polymerisation, thousands of vinyl chloride monomers link together to form the polymer: poly(vinyl chloride).

- PVC is a white powder in its original form.

The animation demonstrates the growing of monomers into a polymer.

Unique Characteristics

- Random positioning of chlorine atoms on the polymer chain makes PVC an amorphous thermoplastic material.
- Modifications of rigid PVC, using additives, bring about improved characteristics.
- The addition of:
  - Heat stabilisers prevent materials from decomposing.
  - Lubricants increase the ease with which molten material flows.
  - Fillers decrease the cost of compounds.
  - Plasticisers render hard, brittle PVC material soft and flexible.
  - Co-polymerisation improve the physical properties of the material.

Applications

- The light in your room and the sound on your radio are dependent on the insulating properties of PVC for safe transmission of low voltage current.
- Transparent bottles, beakers, credit cards, protective coverings for books and tables are used daily by us.
- Sheet materials are used for the protection of cars, the covering of cargo on transport vehicles and the protection of agricultural products.
- PVC piping, fittings, window and door profiles, gutters and drainage pipesare used in the building industry.

- The joy of outdoor sport in our sunshine country depends heavily on PVC: inflatable boats, bags for sport equipment, sport shoe soles, etc.
- Seamless linings for swimming pools, coatings, canal linings and sheeting all make use of the strength and toughness of polyvinylchloride.

Each comment in this paragraph is accompanied by an appropriate visual example.

5.2.4.3 Polypropylene

What is propylene?

- The propylene molecule is closely related to the ethylene molecule.
- One hydrogen of the ethylene molecule is substituted by a methyl group.
- The position of the methyl group on the monomer gives the molecule its specific characteristics.

What is polypropylene?

- Polypropylene is manufactured by an addition polymerisation process using specific catalysts.
- Thousands of propylene monomers link to form the polymer polypropylene.
- Polypropylene is a milky, translucent material provided as small granules.

The animation demonstrates the growing of a polymer from propylene monomers.

Different kinds of Polypropylene

- There are three different kinds of polypropylene if we consider the positioning of the methyl groups on the chain.

- Total random positioning of the methyl groups gives **atactic polypropylene**. During processing of polypropylene, only 2%-5% atactic is produced. Atactic polypropylene has several low volume uses such as its use in the glue industry.
- Ordered positioning of all the methyl groups on the same side gives **isotactic polypropylene**. Isotactic polypropylene is used as a commercial material.
- An increase in the isotactic component of polypropylene, increases the crystallinity and therefore the strength of the material.
- Polypropylene has a density lower than that of water (0,91 g/cm^3). It will start to soften at 170ºC.
- The methyl groups alternate between both sides of the chain – yielding **syndiotactic polypropylene**. This isomer of polypropylene is only now gaining scientific importance and has as yet few uses.

Animations: to demonstrate the difference between atactic, isotactic and syndiotactic polypropylene.

Applications

- Babies all over the world depend on the effectiveness of polypropylene products containing daily food, milk and nutrition.
- Polypropylene is used to manufacture a wide range of household containers, packaging for perishable food, medical appliances and footwear.
- The dream world of a child: playing with toys inside homes, on woven carpets, depends on the versatility of polypropylene.

- In the pharmaceutical industry polypropylene is used to make tamper proof and airtight medicinal containers.
- Polypropylene for wine bottle labeling, nowadays, performs far better than any other material.
- Heavy-duty waste bins from recycled polypropylene, helps in the management and transportation of waste, to keep our neighbourhoods clean.

Each comment in this paragraph is accompanied by an appropriate visual example

5.2.4.4 Polystyrene

What is styrene?

- Styrene is an aromatic hydrocarbon found in such healthy foods as strawberries, apples, beans, fish and milk.
- The chemical structure of the styrene molecule consists of a benzene ring substituting one hydrogen atom on the ethene molecule.
- Styrene, as used in a laboratory, is a clear liquid with a pungent smell.

What is polystyrene?

- Thousands of styrene monomers link together to form the polymer, polystyrene.
- Polystyrene is an amorphous thermoplastic resin produced.
- Animation: growing of a polystyrene macromolecule

An animation shows the growth of the polystyrene molecule.

Unique characteristics

The user has four choices here:
- temperature influence on polystyrene
- polystyrene foams
- copolymers of styrene
- did you know?

Temperature influence on polystyrene

- The chemical structure of commercial polystyrene is atactic, that is: the monomer units are not in any particular order in the chain.
- The random positioning of the monomers causes the materials to be completely amorphous and brittle, with a low softening point temperature of 70° to 95°C.

Polystyrene foams

- Of all the rigid foams on the market, polystyrene and polyurethane foams dominate.
- Steps in the process to manufacture foamed polystyrene:
  - Spherical, expandable polystyrene beads are the starting product.
  - Steam causes expansion of a bead of up to 30x its original size!
  - Steam and pentane (blowing agent) condensate in a cell and leaves a partial vacuum.
  - Air fills the vacuum by permeating into the cells.
  - Softened and expanded pre-foamed cells are put under pressure and fused in a mould.

Styrene copolymers

- Rigid polystyrene is an amorphous, transparent material that can easily be modified to produce tougher materials.

- High-impact polystyrene (HIPS), a combination of styrene and rubbery butadiene, that gives a toughened material with high impact strength.
- ABS is a very strong material made from a mixture of **A**crylonitrile, **B**utadiene and **S**tyrene. It is used as an engineering material suited for use under rigorous conditions.

Did you know?

- Used polystyrene packaging can be recovered from a waste stream, cleaned and recycled for a variety of end-uses.
- Foamed polystyrene conforms to the most stringent international health and safety standards, and is approved for any food contact.
- Foamed polystyrene is created by adding a hydrocarbon blowing agent and thus is ozone friendly.
- Of all household waste, plastic contributes 7% by weight and polystyrene less than 1%!

Applications

- Clear polystyrene has a strong position in the food market, it provides attractive and protective packaging for dairy and delicatessen products.
- The warmth and cosinessof your home is secured by the insulative properties of foamed polystyrene panels, used in walls and on ceilings.
- Ranges of household products and children's toys with very attractive colours can be produced.
- The physical properties of polystyrene can easily be changed to produce shatterproof and inexpensive utensils for use in and around the home.

- The safety and protection of your CD collection is dependent on the stiffness and strength of clear polystyrene.
- The safe transportation of valuable and precious equipment and articles depends on the excellent protective characteristics of foamed polystyrene.
- Pictures: each comment in this paragraph is accompanied by an appropriate visual example.

5.3.4.5 Rubber

Origins of rubber

- Special cells in a variety of plants secrete a white milky fluid called latex. These plants could be:
  - native trees from the rain forests that are cropped for latex by carefully cutting through the bark or
  - a shrub, called Guayule, which is crushed for its sap.
- The latex is coagulated and dried to form a solid rubber called Natural Rubber, sent through pressure rollers, and pressed into sheets
- Hypertext on this screen links to the following information:

  - **Special cells** in a variety of plants produce a white milky fluid. It could be from the broken stems of common weeds or from the bark of certain trees. The latex capillaries of the rubber tree lie in the inner bark or cortex. Cuts to tap the rubber are made into the cortex but not cambium. A cut is 1mm wide and the length of one third of the tree circumference.

  - The Spanish word '**latex**' means milk. Rubber oozes in the form of a milky, white juice from the bark of the rubber tree. The Indians of Central and South America called the rubber tree the *cachuchu,* which means 'weeping wood'.

- **Coagulation** means the changing of a liquid into a thick and solid state.

- Hevea Brasiliensis, a **native tree** of the rain forests of the Amazon basin in Brazil, is the most important source of natural rubber; it is cropped for latex. Another kind of rubber tree, Gutta Percha, is grown in Indonesia and Malaysia. The product of the latter differ from Hevea in its chemical structure and properties.

- **Guayule** is an indigenous shrub that grows in the desert areas of northern Mexico, and southern Texas. The potential of this plant was only exploited after the oil crisis of the 1970's. Its performance capabilities are similar to that of Hevea rubber.

Chemical Structure

- The isoprene molecule is the basic unit of natural rubber
- 200 000 to 400 000 isoprene molecule units link together to form two different polymers: a trans-structure and a cis-structure.
- Picture: isoprene molecule
- Animation: growing of polymer into trans- and cis-structures
- Hypertext on this screen link to the following information:

  - The **isoprenyl repeating unit** is the basic unit of the giant rubber molecule. The general formule is C_5H_8. The double bonds of the monomers are the sites at which polymerisation take place. These bonds can also be broken by reaction with oxygen or ozone, making the material hard and brittle.

  - Two different **isomers of rubber** are important both with the same empirical formula but different structures, they are:

Hevea and Guayule polymerise in a cis-structure (on the same sides of the double bond).

Gutta Percha polymerises in a trans-structure (on the opposite side of the double bond)

Unique Characteristics

Stretching

- Natural rubber has the ability to stretch to 5 or 6 times its original dimensions, and regain its dimensions after stretching.
- We say the material has a wide elastic range where the stress is directly proportional to the strain - following Hooke's Law.
- The material will break down once you have taken it past its elastic limit, e.g. blowing up a balloon.

The animations demonstrate the stretching of an elastic band and give a graphical presentation of Hooke's Law.

Temperature

- Natural rubber, like all other amorphous materials, softens from a rigid material to a fluid when heated.
- The temperature range in which the material softens is called the softening temperature of the material (T_g)
- The T_g of Gutta Percha, a hard and crystalline rubber, is relatively high (70ºC)
- The T_g of Hevea rubber, is lower (-25ºC); a material still flexible in cold weather!

Vulcanisation

- Vulcanisation is the process whereby weak and soft raw rubber material is strengthened.
- Amorphous rubber material consists of a bundle of giant molecules entangled with one another (like long cooked and stirred spaghetti!)
- Sulphur is mostly used as a vulcanising agent, to form chemical cross-links between the molecules.
- Insertion of chemical cross-links between the giant molecules produces a strong network polymer.

The animation illustrates the vulcanisation of rubber molecules.

Crystallisation:

Natural rubber has a dual nature:

- When stretched, it straightens out and becomes crystalline and hard.
- On release, the strands coil back on themselves, resume an amorphous state and the material becomes soft again.

The following is a good example: When a car turns a corner, the part of the rubber wheels bearing the mass, is stretched and therefore strengthened. On releasing the tension, the rubber, now in an amorphous state, is fit again to absorb road shocks!

Synthetic Rubbers

- The requirements of advanced technology and the world's demand for rubber can not be satisfied by natural rubber alone.
- Synthetic rubbers meet the demand for special rubber types and can be tailor-made for practically any application.

The user has different options to choose from and can access information on the following synthetic rubbers:

Isoprene
Silicone rubber
Butadiene rubber
Chloroprene
Butyl rubber
Ethylene/Propylene

Applications

- Natural rubber, in combination with other rubbers, remains popular in the tyre industry because of its excellent mechanical properties and low heat build-up.
- Rubber has outstanding shock absorbing qualities and is extensively used as a shock absorbing material in sports equipment and in industry.
- A melt processible rubber is the answer to effective electrical connectors and plugs.
- Latex rubber, in aqueous dispersion, is used to make gloves for hygienic circumstances.
- Water sport is entirely dependent on the body heat insulative and protective characteristics of neoprene, for example wet suits.
- Imagine walking from home to school without the comfort and protection of rubber soles on your shoes?

Pictures: each comment in this paragraph is accompanied by an appropriate visual example.

5.2.5 Questions and Answers

The Questions and Answers section is an opportunity for self-evaluation on synthetic polymer materials.

Questions are constructed as follows:

- Drag and drop questions
- Multiple choice questions
- Questions where text and pictures must be linked.

The following topics are evaluated:

- Identification codes
- Chemical structures
- Classification of materials
- Polyethylene
- Poly(vinyl chloride)
- Polypropylene
- Polystyrene
- Rubber

5.2.6 Help Files

Help files are, most of the time, the last bit of information the user will access. Important information regarding use of the program, basic navigation and overall design, is available from any window in the programme.

The Help Files are the only files in this programme using a scroll bar to access more information, seeing that this is not part of the lecturing/learning programme. The user has the choice to exit at any time – back to the main page of the Help Files and from there to navigate to any of the appropriate chapters.

The following topics provide answers to the most frequently asked questions:

- Outline of the programme
- Objectives of the programme
- Navigation through the programme

Help files explaining the layout and information of a section, give a clear picture of what the user can expect.

Chapter 6

Practical Experiments

6.1 Introduction

Effective learning of polymer science can only be successful when students have hands-on experience. Demonstrations, of different polymer science phenomena, were initially part of the lectures and multimedia presentations of "Fun with Polymers". These demonstrations developed into full scale practical activities for students. Practical activities for primary school students are used to demonstrate important polymer principles for secondary school students.

Some of the concepts used and developed in these experiments can easily be found on the INTERNET or in industry. For example: the fact that a mixture of borax and polyvinylalcohol will result in a slimy polymer or that liquid latex will start to gel on exposure to air. But, nowhere can the details and minor adjustments in the methods of these activities be found to save a teacher the embarrassment of an unsuccessful experiment! For example: the fact that polyvinylalcohol granules take hours to dissolve in water and that after 24 hours the solution will not cross-link with a borax solution; or that the correct formulation of the ingredients of a poly(vinyl chloride) eraser (plasticiser, stabilizer and pigments) is essential to prevent the final product from degradation at 180°C. Detail of these experiments and correct methods to streamline these practical activities with local science curriculums and circumstances took hours to establish, as pointed out in the chapter on evaluation.

Evaluation of the practical programme (chapter 7) showed that:

- Just a small percentage of teachers and students have tried to find or access information on polymer science on the INTERNET or in industry! This information is as close as a few keystrokes on the computer or an industrial site sometimes quite close to a school.
- the supply of chemicals and availability of suitable apparatus are always major problems in performing practical activities. Teachers do not have time or knowledge to plan and bring the different components together.

The primary school programme deals with six practical experiments. The exact copies of the teacher's manual of these practical experiments, to be marketed in 2002 by a microchemistry company in South Africa, are presented in the next paragraph.

The selection of practical activities were done with the following in mind:

- to take students from known experiences to the unknown world of synthetic polymer materials
- to bring them in contact with as many different plastic materials as possible
- to let students experiment with save chemicals used to create plastic materials and products
- to let students have fun while learning about polymer science.

The following critical and cross-field outcomes will be achieved during the performance of the practical experiments:

- Work in a team.
- Tasks are shared between two students and knowledge shared with the rest of the class.
- Identify and solve problems.
- Practical related identification, recently gained experience and creative thinking are required for the performing of the experiments.
- Students have to communicate skills by demonstrating their results and findings.
- Describe and discuss the impact of materials on our environment, their advantages, disadvantages, applications and uses.

The secondary school practical programme (not part of this thesis) is build around more advanced polymer science concepts with detailed information for the teacher on concepts like cracking of ethane, natural and synthetic rubbers, silicone, polyurethane, polyester resins and activities like recycling and re-using of plastic materials. Entrepreneurial skills are challenged and students have the opportunity to start a small business with knowledge, chemicals and equipment available.

6.2 Experiments

6.2.1 Identification of plastic materials.

Identification of different plastic materials is seen as the first step to bring a student in contact with plastic materials in his/her local environment. The learner not only starts to differentiate between plastic materials but are also directed into the broader picture of the influence of synthetic polymer materials on the environment.

The practical activity is designed to use well-known chemicals, apparatus and simple methods to identify everyday plastics. It ends with the important identification flow diagram and identification logo table used internationally to identify major plastic materials.

Identification of plastic materials by the flame testing method is for safety reasons left to the teacher as a demonstration.

Subject specific outcomes:

- Touch different plastic materials
- Differentiate between six known plastic materials
- Identify unknown plastic materials by using the senses:

  touch, smell, observe and hear
- Compare and discuss characteristics of different plastic materials
- Explain physical differences between plastic materials

Discuss the impact of plastic materials on the environment.

Experiment 1

AIM: To assess various physical, chemical and thermal properties of plastic materials around you.

REQUIREMENTS:

APPARATUS	CHEMICALS
Pencils 4B, 2B, HB, 2H, 4H Matches Microburner Copper rod 6 known plastic material samples NT cutter or scissors*	Different materials chosen from the table Methylated spirits PRESTIK Alcohol SUGAR Distilled water Tweezer Prestik®

*Not provided

PREPARATION:

Time: 0-10 minutes

Collection of any plastic material one day in advance

1. Students work together in pair.
2. Each pair should have a package of 6 samples of different plastic materials.
3. Names of the materials are embossed on the samples. For each name there exists and intenational acronym:

Name	Acronym
Polyethylene terephthalate	PET or (PETE in US)
High-density polyethylene	PE-HD or HDPE
Poly(vinylchloride)	PVC
Low-density polyethylene	PE-LD or LDPE
Polypropylene	PP
Polystyrene	PS

4. The method of experimentation involves all the senses: touch and sight, hearing and smell.
   A series of typical identification tests will be performed:
   - **transparency** testing
   - **hardness** testing
   - **density** testing
   - **flame** or thermal testing (performed only by the teacher)

5. Collect, one day in advance, any discarded plastic material in your environment. You will perform **a final identification test** on this material.

PART 1:
PHYSICAL APPEARANCE: TRANSPARENCY

PROCEDURE AND OBSERVATIONS
TIME: 10-15 MINUTES

1. Group the unpigmented samples into the following categories according to their transparency relative to window glass. (Leave category 3 out)

DATA TABLE FOR TRANSPARENCY TESTING

	PET	HDPE	LDPE	PP	PS
About the same as window glass	✔				✔
Inferior to window glass				✔	
Opaque		✔	✔		

QUESTIONS/ANSWERS

1. Which samples' transparencies are about the same as window glass?

   PET and PS

2. Is it possible to distinguish between different plastic materials by comparing the transparencies of the samples?

   It is possible to broadly distinguish between plastic materials by comparing physical properties (like transparencies), but definite identification needs further testing. Appearance, feels, scratching or back and forth bending of a plastic material often give very good indication as to its type.
   Already two groups of materials emerge:
   PET and PS are materials with good transparencies close to that of glass;
   PP, HDPE and LDPE are all materials with low transparencies.

3. 3.1 Could some of these materials be a substitute for glass?

   Yes, PET and PS. Polycarbonate and PERSPEX are two other materials (mote likely) to be used as substitutes for glass.

   3.2 Name one positive and one negative reason for a plastic material to be used as a substitute for glass:

   Positive: plastic materials are cheaper and weigh less than glass; glass shatters when it breaks;
   Negative: plastic materials scratch easily and cannot withstand high heat exposure.

PART 2
HARDNESS

Procedure and Observations
TIME: 10-15 MINUTES

1. Test and observe the flexibility and stiffness of the different samples by **bending** and **twisting** the samples.
2. Distribute pencils with hardness 4B, 2B, HB, 2H and 4H and try to **scratch** the surfaces of the different samples.
3. Complete the following table and indicate (with a √-mark) which pencil will leave a scratched mark on the surface of the material or not.
   Remember: The pencils are classified according to hardness: 4B is the softest and 4H the hardest

DATA TABLE FOR HARDNESS TESTING

Pencil	*1*	*2*	*3*	*4*	*5*	*6*
4B	✗	✗	✗	✓	✗	✗
2B	✗	✗	✗	✓	✗	✗
HB	✗	✓	✗	✓	✓	✗
2H	✗	✓	✓	✓	✓	✗
4H	✗	✓	✓	✓	✓	✗

3. Drop pieces of different materials on a hard surface and listen to the sound.
4. Complete the following table and indicate (with a √-mark) the sound of the different materials.

DATA TABLE FOR SOUND TESTING

	1	*2*	*3*	*4*	*5*	*6*
Metallic						✓
Dull	✓	✓	✓	✓	✓	

QUESTIONS/ANSWERS

1. Which materials would you classify as:

   1.1 hard and brittle? *PS*

   1.2 soft and flexible? *LDPE, PVC and PET*

   1.3 hard but also flexible? HDPE and PP

2. 2.1 Which materials do have a hardness >HB?
   PS and PET (PVC can be classified with hardness close to the HB-pencil)

   2.2 Which materials do have a hardness <HB?
   LDPE, HDPE and PP. These materials have chemical structures closely related and are called the polyolefins.

3. Which material has a metallic sound when dropped onto the floor?
   Polystyrene

PART 3
DENSITY
PROCEDURE AND OBSERVATIONS
TIME: 30-45 minutes

1. Secure three glass vials with some Prestik® on the table.
2. Fill half of the first vial with ethylalcohol (+/- 10ml or the height of two fingers).
3. Fill ¼ of another vial with distilled water (+/- 5ml or the height of one finger) and add the water to the ethylalchol. A 3:1 solution.
   Mix thoroughly. ($\rho_{\text{alcohol solution}} <$ *1,00g/cm³*).
4. Half fill the second vial with distilled water (+/- 10ml)($\rho_{\text{water}} =$ *1,00g/cm³*).
5. Half fill the third vial with distilled water (+/- 10ml) and add two stirring rod tips of sugar to the water. Mix thoroughly. ($\rho_{\text{water}} >$ *1,00g/cm³*).
6. Clearly mark the different vials with the labels provided:
   sugar solution, distilled water and alcohol solution.
7. Take the PET-sample and cut three slivers off the sample.
8. Drop a sliver in each of the three solutions. (Remember to break the surface tension with the stirring rod!)
9. Does the sample **float** or **sink**? Write down your observations.
10. Complete the density test for the remaining five samples.

DATA TABLE FOR DENSITY TESTING

Plastic Material	Solutions		
	Water with alcohol *(ρ < 1,00g/cm³)*	**Distilled water** *(ρ = 1,00g/cm³)*	**Water with sugar** *(ρ > 1,00g/cm³)*
Polyethylene terephthalate (PET)	sink	sink	sink
Polyethylene High Density (HDPE)	sink	float	float
Poly(vinylchloride) (PVC)	sink	sink	sink
Polyethylene Low Density (LDPE)	float	float	float
Polypropylene (PP)	float	float	float
Polystyrene (PS)	sink	sink	float

QUESTIONS/ANSWERS

1. What does this test tells you about the densities of plastic materials?
   Different materials have different densities and a simple test can let us distinguish between the plastic materials

2. Could there be any similarities in the characteristics of HDPE, LDPE and PP?
   Yes. They all float on water and the sugar solution indicating densities closely related. There chemical structures are also related and therefore there characteristics are related. We call them the polyolefins.

3. Speculate how recyclers might use relative density tests to separate different plastic materials for recycling.
   Firstly, the materials are all washed and shredded. Then the shredded material is dumped in solutions of increasing densities. Material floating on the surface can be removed and should be of the same density and type.

4. 4.1 In which solution does HDPE sink but LDPE floats? *Alcohol solution*
   4.2 Does that tell you something about the density of the different polyethylene materials?
   The name high density PE indicates a higher density and therefore this material will sink. Low density PE will float; its density is lower than that of HDPE.

Part 4: FLAME TESTING
PROCEDURE AND OBSERVATIONS

TIME: 30-45 minutes

The teacher should perform the flame testing experiment on materials of all six categories.

1. Fill a micro-burner with methylated spirits and secure it on a tile (not on a piece of paper!).
2. Remove all flammable material/solutions and light the micro-burner.
3. Cut a piece as big as a fingernail from the PET-sample, use the tweezer and put it in the flame.
4. Note the following: does it ignite easily; the colour of the flame; is there any smoke and the colour of the smoke; describe the smell (if any); does the sample stay on burning after it has been removed from the flame; does it drip?
   NB: The tweezer is made of HDPE – DO NOT let it catch fire!
5. Record the observations.
6. Test HDPE, LDPE, PP and PS likewise, **but not PVC**.
7. For the PVC test: heat the copper wire in the flame. Use a piece of Prestik® to prevent your fingers from burning!
8. Melt the PVC sample with the hot wire and put the copper wire, coated with PVC, back into the flame.
9. Record your observations.

DATA TABLE FOR FLAME TESTING

	PET	PE-HD	PVC
Ignites	*easily*	*easily; drops while burning*	*difficult*
Flame	*orange/yellow*	*bright yellow with blue centre*	*burns with typical green flame on copper wire*
Smoke	*sooty black*	*little white*	*white*
Smell	*no smell*	*like burning candles*	*acrid, acidic*
Removal from flame	*burns for a short time; drips*	*burns for a while*	*stops burning*
	PE-LD	**PP**	**PS**
Ignites	*easily; drops while burning*	*easily; drips while burning*	*easily*
Flame	*bright yellow with blue centre*	*bright yellow with blue centre*	*big yellow flame*
Smoke	*little white*	*little white*	*sooty black*
Smell	*like burning candles*	*like burning candle wax*	*typical sweet smell*
Removal from flame	*burns for a while*	*still burns and drips*	*burns heavily; does not drip*

Part 5:
EXTRA ACTIVITIES

Students should be able to identify plastic materials using simple test methods. As a final task let each student collect one material in his/her environment coming form the list of materials provided on the next page/diagram. Let them perform a series of tests and identify the material correctly according to the flow diagram on the last page.

A LAST WORD ON IDENTIFICATION...

The first step in recycling of plastic materials is to identify materials correctly. However, it could be a daunting task, especially if you have a bunch of transparent containers made, for example, from polyvinylchloride (PVC), polystyrene (PS), polycarbonate (PC) or polyethylene terephthalate (PET). Without a laboratory, identification is an impossible task.

The Society of the Plastics Industry (SPI) in the USA introduced a system of identification which is of great value to the public in sorting plastics into generic types for recycling. The SPI logo or sign or pictogram does not infer recyclability – it only identifies packaging materials.

Indentification Symbol	Plastic Material	Products
1	Polyethylene terephthalate PET	Audio/video tapes; coke bottles; soft drink bottles; rope; fabrics; compact discs
2	Polyethylene High Density HDPE	Milk jugs; supermarket shopping bags; detergent bottles; flowerpots; trash cans; crates
3	Polyvinylchloride PVC	Drainage and sewer pipes; drip bags and medical tubing; cooking oil and vinegar bottles; outdoor furniture; credit cards; shoe soles; floor tiles; wallpaper
4	Polyethylene Low Density LDPE	Squeezy bottles; wrapping film; container lids; flexible heavy gauge bags; crates
5	Polypropylene PP	Glass-clear packaging film; carpets; yoghurt cups; crates; lab equipment; crates; medicinal containers; bottle caps; toys
6	Polystyrene PS	Display boxes; pens; CD cases; disposable cups and cutlery; construction; insulation; toys; cosmetic jars
7	All other polymers	

A Simple Method for the Identification of Common Plastics

1. Attempt to cut a thin sliver off the edge of the moulding

Powdery chips → indicate a hard **thermoset** material

2. Hold the moulding to a microburner and smell. (Ask teacher)

Fishy smell of a white or brightly coloured sample → **melamine or urea formaldehyde**

Fairly coherent sliver → **thermoplastic**. Bends easily (Optional: melts easily)

2. Drop the moulding a few centimeters on a hard surface.

Metallic noise → a styrene-containing polymer. Hardness>HB

3. Burn a small piece of moulding (Ask teacher)

Sweet smell of styrene indicates **polystyrene** sample.

A dull noise precludes polystyrene.
3. Place sliver in distilled water.

Sliver floats.

4. Attempt to scratch moulding with fingernails

High gloss moulding that does not scratch → **polypropylene**

High gloss moulding scratches to some degree → **high density polyethylene**

Scratches fairly easily → **low density polyethylene**

Sliver sinks → not a polyolefin
4. Burn a small piece of the moulding; observe flame and ease of burning. (Ask teacher)

Burns with a yellow flame.
5. Blow out flame; smell vapour.

Smell like methylated spirits → **PMMA or PERSPEX**

Burns with difficulty.
5. Observe colour of flame while moulding ignites.

Greenish flame.
6. Remove heat source and smell vapour

Acrid, acidic smell, sputtery when burning, flexible moulding → **polyvinyl chloride**

Yellow flame.
6. Remove heat source and smell vapour

Distinctive smell like burning hair.
7. Press cold copper wire to heated sample and draw it away.

If threads form → **Nylon**

6.2.2 Talking Trash

Correct identification of plastic materials equips the student with knowledge to have an impact on his/her immediate environment. Practical application of this knowledge is the incentive for the experiment: "Talking Trash". Just to see and realise the amount of trash generated daily by one household is enough to get students involved in a project to accumulate statistics about our through-away society.

The experiment deals with daily disposal of garbage recorded over a two week period, from a student's own household,. The amount of plastic and other materials are closely monitored and calculated. Combined results from the whole class are then calculated and published in the school's newspaper. These results always sparked some heated discussion on the fact that trash will be gone today but back tomorrow!

The students are then challenged to work in groups and create something useful from discarded plastic materials or dispose of the materials correctly by identification of local companies involved in recycling or re-using of materials.

Subject specific outcomes:

- Separate glass, paper, metal, plastic materials and other disposable matter
- Use knowledge acquired from 'Identification of Polymer Materials' to separate plastic materials
- Keep track of items in the trash can by daily tabulation of data on a data sheet
- Calculation of final results
- Publish final results in a newspaper

- Create something new from the old discarded materials
- Get involved in recycling and re-using of plastic materials and identify and support companies involved in recycling and re-using of plastic.

Experiment 2

"Like energy, matter is neither created nor destroyed;
it simply changes form;
so is the trash in your trash can!"

AIM:
It is time to become familiar with trash generated from your home. You will identify and separate different garbage materials and calculate the percentage of each material.

REQUIREMENTS:
5 x heavy-duty bags (not provided)
Disposable gloves

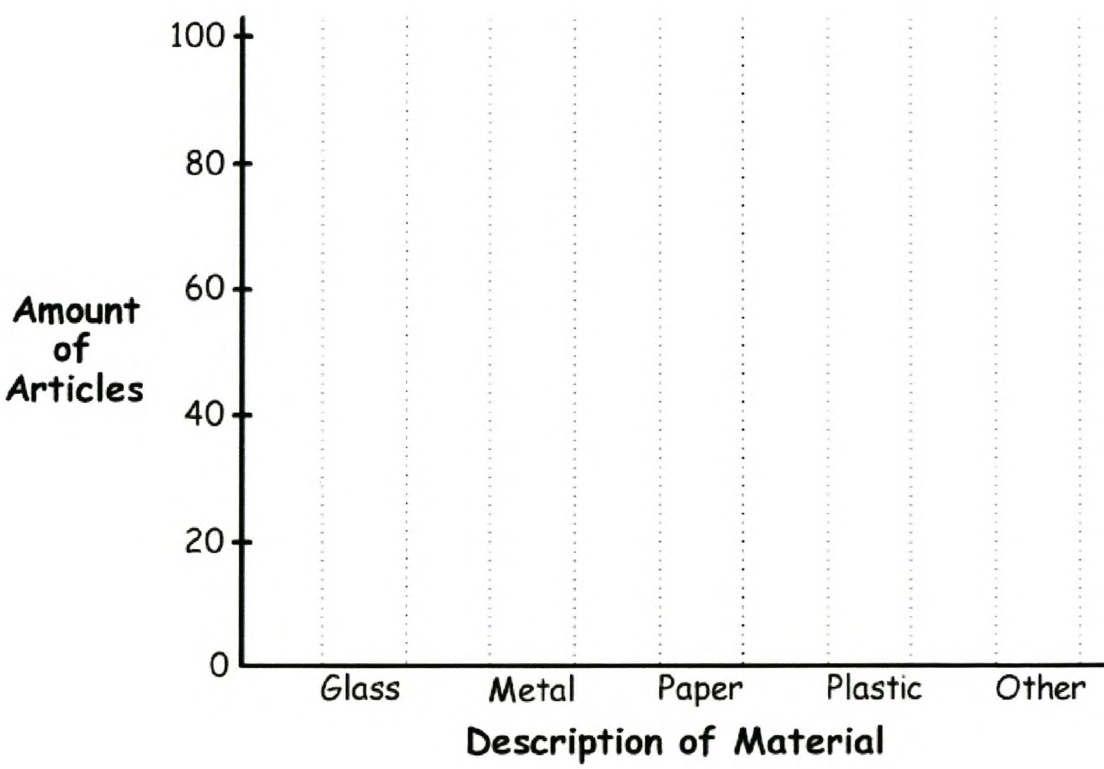
PROCEDURE:
Time: 2 weeks

1. This project runs for **two weeks** and can be completely done at home. The class may be divided in different groups for this project.
2. Mark five different large garbage bags for the following materials:
   "Paper", "Metal", "Plastic", "Glass" and "Other"
3. Start the project by daily separating the organic waste (like food and plant material) from the inorganic waste (paper, metal, plastic, glass and other dried materials). You are going to monitor the inorganic waste.
   Remember to use disposable gloves to protect your hands!
   Organise your household members to assist you in this matter.
4. Use the **data sheet** on the next page, describe the type and **daily notify** the amount of articles in each container before it is disposed of.
   (Use your knowledge of the Identification Experiment and identification logos to identify the plastic articles).
5. Complete the data sheet after two weeks and calculate all the subtotals.
6. Let the students bring their results to the classroom and help them calculate the **percentage (%)** values for each material according to the following formula:

$$\frac{\text{Amount of articles in section}}{\text{Total amount of articles in experiment}} \times 100 = \dots\dots$$

7. Each student or group should complete a **bar graph** on the next page. Use coloured pencils and draw bars for the amount of articles of each material.
8. With the percentage values available, complete the **pie chart** on the next page for the five main groups of materials in your garbage bag. Again use coloured pencils for the different sections of the pie! Write the names of the materials on the different sections of the pie chart.

Bar Graph for the Amount of Articles per Material



DATA SHEET FOR TALKING TRASH

	DESCRIPTION OF ARTICLE	AMOUNT OF ARTICLE														Sub-Total	%
		WEEK 1 (7 days)							WEEK 2 (7 days)								
		1	2	3	4	5	6	7	1	2	3	4	5	6	7		
	Coloured glass	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	Transparent glass	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
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	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....
	Soft drink cans	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	Tin foil	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
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	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	...	.....
	Newspapers	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	Glossy magazines	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	Tissue paper	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	Foil coated paper	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	..,..	.....
	PET	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	PE (HD and LD)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	PVC	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	PP	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	PS	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	Other	....	....	....	....	....	....	....	....	....	....	....	....	....	....	..,..	.....
	Fabric	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	Ceramics	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
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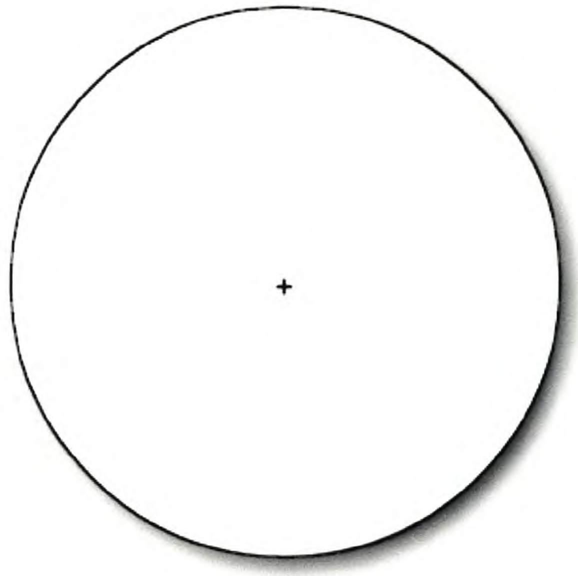
		....	....	....	....	....	....	....	....	....	....	....	....	....	....	.,...	.....
														TOTAL			

Pie Chart for the five main groups of disposable materials



QUESTIONS/ANSWERS

1. List all the activities at your home generating inorganic trash.

Use of tubes and bottles in bathrooms; all the containers for fresh food, milk and juices in the kitchen or on the porch after the previous "braai"; reading of daily newspapers and weekly/monthly magazines; gardening producing broken pots for plants; broken ceramics in and around the home; used CD-cases; worn-out shoes and other clothing….

2. What happens when trash leaves your home?

Out of sight (and smell), out of mind…just to be back on our beaches or doorstep the following day! "Out of sight" means the local landfill or enormous barges taken to landfills where we can't see them; our rates and taxes pave the way for this convenient way of disposal. The cheapest landfills are most of the time the very sensitive ecological marshlands breading places of rare species of birds/animals. Shocking evidence has revealed that very little decomposition occurs where moisture and oxygen are absent. That leaves us not only with the wind blowing paper and plastic material in all directions but also with organic material not decomposing!

3. List dangers of materials not been correctly disposed of:

Local groundwater may get polluted;

Heavy metals like household batteries, can start disintegrating and the fluids will slowly filter through the soil;
Motor oil can contaminate precious top soil;
Paper and plastic bags may clog natural waterways, be dangerous to animal life;
Pieces of broken glass are a thread to human and animal safety;
Containers with pesticides start to leak contaminating natural water resources.

EXTRA ACTIVITIES:

1. Collect and summarise all the data in your classroom, and write an article to your school or local newspaper, publishing statistics on our throw-away society. A pie-chart gives an excellent overview of waste disposable in the average home in your region, and could be very important information to your municipality!

2. Start your own recycling project.
   - Blue disposal containers for glass and orange disposal containers for paper are everywhere; just locate them!
   - Take the local *Yellow Pages* and collect addresses and telephone numbers of companies investing in recycling. Search under the following topics:

   Recyclers
   Newspaper recycling,
   Paper recycling
   Mondi recycling
   Waste paper
   Plastic recycling
   Collect-A-Can

3. Run a competition where groups of students have to design a miniature amusement park for pre-primary school kids by using only discarded plastic materials.

6.2.3 Painting with liquid latex

Working with liquid latex starts as part of a demonstration to show different ways to create a plastic product. The learner can easily relate to rubber as one of the oldest and best known polymer materials. The practical activity allows the learner to create a colourful painting by using natural rubber's ability to gel.

Experimentation with natural rubber connects the learner to the vast world of rubbers around us. Liquid latex that gels, while exposed to air, is one of the oldest methods used to make polymer materials to suit our needs. Synthetic rubbers start as an imitation of the natural product and nowadays dominate the shoe and sports world.

Subject specific outcomes

- Touch, feel and smell of liquid latex
- Design of own painting on fabric; mix of pigment
- Use of a neutralisation reaction to cross-link the liquid latex
- Read about the rubber industry and the interesting history behind modern rubber materials.

Experiment 3

AIM: Liquid latex is a natural polymer used by man for thousands of years. This experiment shows you how to paint a piece of fabric with colourful liquid latex and preserve your painting.

REQUIREMENTS:

Apparatus	**Chemicals**
3 x paper cups	Liquid latex
3 x small paintbrushes	Acetic acid (vinegar)
1 x stirring rod	Different colours of tempera paint
Paper towels	Warm, soapy water*
Stencils	
Safety glasses	
Fabric or old T-shirt (white/pastel colours)	
2B pencil	
Apron	
Black marker*	
Old newspapers*	

*Items not provided

PREPARATIONS

Time: 0-15 minutes

1. Although students create their individual paintings, they work in pairs sharing the liquid latex and brushes.
2. Stencils are included as examples. Students may draw their own original designs. Refrain from detailed drawings – large open spaces, to paint work best.
3. To speed up the polymerisation of liquid latex (step 5), have a bowl or spray bottle ready with acetic acid.
4. Cover the working surfaces with old newspapers. The newspapers will also prevent the paint from bleeding.

SAFETY

1. Students should wear old protective clothing or an apron to protect their clothes. Once liquid latex solution sets into the rubbery form on fabric, there is no easy or safe way to remove it.
2. Work in a well-ventilated area. Liquid latex contains ammonia as a stabiliser and the vapours can damage the eyes. Students doing the mixing should wear safety glasses.
3. Should there be any contact with the eyes, rinse the affected area and seek medical attention.
5. If some of the latex has dripped/spilled on the floor or table, wait until it has polymerised and rub it off.

TEACHER'S DEMONSTRATIONS

Demonstrate the principle of this experiment by using a small amount of liquid latex and acetic acid:

1. Pour 20ml of liquid latex in a 75ml cup.
2. Pour 20ml acetic acid in another 75ml cup.
3. Dip the bottom of a 50ml plastic container (container of the liquid latex) in the cup with liquid latex and allow the excess to drip for a few seconds.
4. Put the bottom of the container for a few seconds in the acetic acid or leave it for at least half an hour to dry.
5. Cut the dried latex film at the bottom and carefully roll the latex to make a rubber band and leave it for a few minutes before testing its strength.
6. A finger can also be dipped in the liquid latex and acetic acid to make smaller rubber bands.

Compare the strength of different rubber bands with one another.

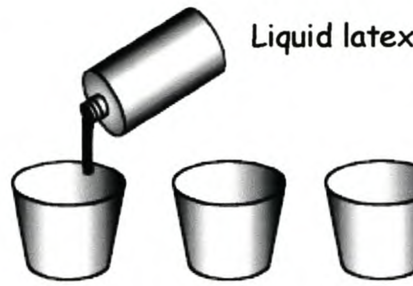
PROCEDURE:
Time: **1hour**

Step 1

Decide on a design for your T-shirt or piece of fabric.
If you are not able to draw a freehand sketch, use the examples provided and cut out different stencils.
Use the 2B pencil and draw your design on the fabric.

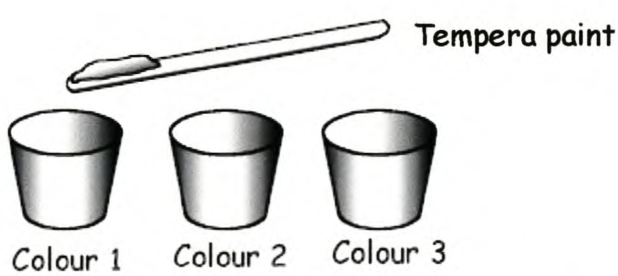
NB: DO NOT draw a detailed sketch! Clear and simple sketches with large spaces to paint, are the best. Liquid latex is more difficult to paint with than ordinary paint.

Step 2



Pour 10-15ml liquid latex in **three** different 75ml paper cups. (Clean the mouth of the container and close it immediately. Leaving the container open will expose the liquid latex to air and it will start to gel!)

Step 3



Decide on three colours you want to use in your design. (You and your partner should have 6 different colours between the two of you).

Add 5g of tempera paint (tip of a stirring rod) to the paper cups and mix carefully and thoroughly with a stirring rod.

Use the stirring rod for the other two colours too, but clean it first with a paper towel. (For darker colours, add more paint)

Step 4

Paint lightly and gently scrub the paint into the cloth with the paintbrush.
NB: Rinse the brushes immediately after use with warm soapy water!

Step 5	**Step 6**
Put the painted fabric in a washing basin and sprinkle it with acetic acid. Cover all areas. To remove the acetic acid, rinse it with water. Do not wring the fabric; it may be still sticky.	Put your artwork on a flat surface and leave it overnight. If your design needs some touch-up, use a black marker to accentuate the outlines. To clean the paper cups, just leave the paint to dry and rub it off the following day. If you have forgotten to clean the paintbrushes, carefully pull the rubber from the bristles and use again.

EXTRA ACTIVITIES:

The use of liquid latex can be extended to other activities as well.

- Any shoes made of a white/pastel colour fabric, or material hats can be used instead of T-shirts.
- The fabric, used in the experiment, can be the front part of a pillowcase.
- Any hardened foamed polyurethane products, made in the experiment "Foamed Polyurethane", can be painted with colourful liquid latex.

QUESTIONS/ANSWERS

1. a) How would your life be influenced by the **absence of rubber**?
   b) What are the different **uses of rubber**?

   Think about the following uses of rubber and picture your world without it!
   - *tires of vehicles*
   - *soles of shoes*

- *shock absorbing articles in engines, sport equipment*
- *insulating material for electrical plugs and connections*
- *protective clothing like diving suits, gloves, raincoats*
- *rubber bands*

2. Find out who **Charles Goodyear** was and his contribution to the rubber industry.

   Charles Goodyear started to experiment with natural rubber already in the summer of 1834. Although the "rubber fever" in the early 1830's had ended as suddenly as it had begun, Goodyear still believed that the waterproof gum from Brazil "is probable one of the only inert substances" and it "excites his mind". The problem was that rubber suffered from the disadvantage of being susceptible to changes of temperature, becoming sticky when hot and hard when cold.

   In and out of jail, for debt charges, he worked on possible solutions to modify the chemical properties of natural rubber. In 1840 he started to experiment with sulphur and by accident spilled some sulphur filled rubber on a potbellied stove. The result was a charred leathery material that changed our world! He unfortunately sold the manufacturing interests and never reaped the benefits of this amazing invention.

   Today there is a cultivated tree for every two human beings on earth. Millions of people earn their livelihoods in rubber manufacturing, and produces numerous different rubber products.

3. The latex you used for painting was first a liquid, then became sticky and later congealed into a solid. How is it possible?

   Liquid latex consists of rubbery molecules, polyisoprene, in a watery suspension. The material will immediately start to gel on exposure to air. The latex starts to harden and forms an amorphous sticky mass.

   To prevent the material from hardening, ammonia liquid is added. The acetic acid neutralises the ammonia and forms the final product.

4. What is the difference between natural rubber and synthetic rubbers?

   An enormous demand for rubber products, the previous century, forced chemists to invent synthetic rubber with characteristics close to natural rubber. Today, names like polyisoprene, polybutadiene, neoprene, silicone rubber are all household names. Chemists actually copied Mother Nature and started to produce synthetic rubber with the same chemical structure than natural rubber. The only difference is that synthetic rubbers originate from the petroleum industry.

BACKGROUND INFORMATION...

Natural rubber is one of the oldest natural polymers of our society and used for ages in the tropical forests of South America. There is no record of rubber or rubber trees prior to the discovery of America when Columbus, on his second trip (1493-1496), found it in Haiti. It comes from the tree Hevea Brasiliensis and is produced worldwide, mainly in tropical regions. Natural Rubber is actually a generic name for rubbers cultivated from different plants and rubber trees.

An enormous demand for rubber products, during the 1930-1940's, forced chemists to invent synthetic rubber with characteristics close to natural rubber. The corresponding development in the production of petroleum products not only sparked the growth of the plastic industry, but played an important part in the manufacturing of synthetic rubbers. Today, names like polyisoprene, polybutadiene, neoprene are all household names. Just a look at your sport shoes and a car tire tells the excellent story of this wonder material!
The word latex is a Spanish word, meaning 'milky solution' while the Indians from Central and South America calls the rubber tree 'weeping wood'. The milky solution contains very small globules suspended in water and on exposure to air, hardens into a rubbery solid. Liquid latex in a rubber tree works like blood in the human body: the tree starts to 'bleed' and on exposure to the air, it becomes a thickened or gelled mass to prevent further loss! To keep the latex from hardening, ammonia is added. When the fabric is painted, the latex penetrates the material and is removed by rinsing it with acetic acid. A neutralisation chemical reaction occurs between the base and acid and the gelled latex sets into the fabric, producing the final artwork!

Rubber consists of giant macromolecules called polyisoprene. They are all together in suspension like a container filled with spaghetti suspended in water. The macromolecule is called a polymer (polyisoprene) and consists of thousands of repeating small units called monomers (isoprene).

6.2.4 Creating with plasticised poly(vinyl chloride)

Developing polymer-based products with specific properties and capabilities are basic tasks for a polymer chemist. This experiment challenges the student to prepare an eraser from poly(vinyl chloride) powder.

Poly(vinyl chloride) is a rigid, clear, unworkable material and growth in the PVC market only started once appropriate additives appeared. This practical activity consists of exactly the same chemicals used in industry although the manufacturing process is adapted for classroom activities. The student uses some of literally hundreds of additives to tailor make a final product. A plasticiser changes the PVC powder into a workable piece of material; the correct amount of stabilizer is used to prevent the final product from degrading in the oven and an inorganic pigment is used as a colourant.

Trial experiments to arrive at the final formulation and the time spent at an elevated temperature, were made to give the student the exact information he/she needs to be successful in creating an eraser.

Subject specific outcomes

- Touch and measuring out of poly(vinyl chloride) powder
- Observe the influence of a plasticiser (DOP) and a staliliser (Ba/Zn) on the properties of the product
- Differentiate between an eraser with an abrasive and an eraser without an abrasive
- Discuss the effect of pigment on the material structure
- Compare the properties of a home-made eraser to a commercial eraser
- Discuss the influence of a stabilizer to prevent degradation of the material.

Experiment 4

AIM: Developing polymer-based products with specific properties and capabilities are basic tasks for polymer scientists. This activity challenges students to prepare an eraser from poly(vinylchloride) (PVC) powder using different additives influencing the properties of the eraser.

REQUIREMENTS:

APPARATUS	CHEMICALS
1 x 250ml paper cup 1 x 75ml paper cup 1 x stirring rod 2 x 20ml glass vials Apron NT cutter or scissors* Oven at 180°C*	Plasticiser PVC powder Stabilizer Coloured chalk Sand or pumice (an abrasive) Warm soapy water*

*Items not provided

PREPARATIONS:

Time: 0-10 minutes

1. Cover the working surfaces with old newspapers.
2. The PVC-powder plastic bag contains powder for 2 erasers per student. The stabilizer propette has stabilizer for 2 erasers per student.
3. The final product will be baked in an oven at 180°C. Put the glass vial, with the final product, on a piece of tin foil or on a plate to protect the oven.
4. Yellowing/browning of the final product indicates degradation. Take the product immediately from the oven.
5. Too much PVC-powder or pigment will cause the final product to crumble.
6. Distribute the different colours and sand between the students.

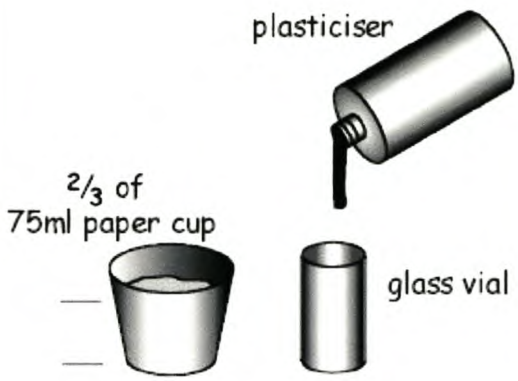
SAFETY:

1. Wear an apron. Care must be taken when mixing all the different ingredients. DO NOT spill plasticiser on your clothes. If so, remove immediately with warm, soapy water or with CCl_4, if available
2. The glass vial with your final product is hot; leave it to cool down before it is removed. Take care not to break the glass vial when removing the eraser.

PROCEDURE:

Time: 10 minutes to perform the experiment
60 minutes baking time and 20 minutes cooling time

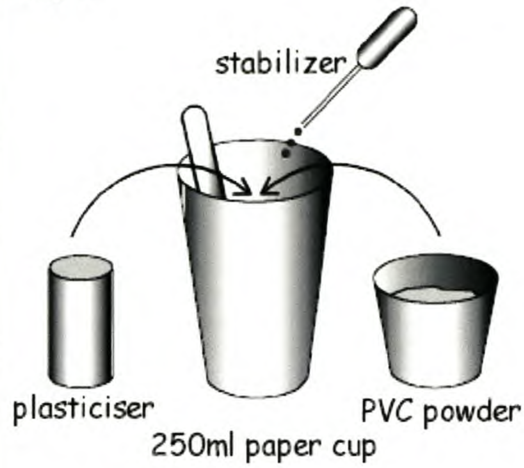
Step 1



Open the container with **plasticiser** and fill one of the glass vials to the top with plasticiser. Close the container immediately.

Fill $^2/_3$ of a 75ml paper cup (16g) with **PVC powder**.

Step 2



Carefully add the **PVC powder** and the **plasticiser** to the 250ml cup.
Cut the stabilizer propette and add 5-7 drops of **stabilizer** to the mixture. Seal the propette again with heat (match)

Stir thoroughly until the plastisol mixture has a smooth and creamy texture.

Step 3

Decide on the kind of eraser you want:
Example 1:
Choose a piece of **coloured chalk**. Use an NT- cutter or scissors to scrape finely divided powder from the chalk.
(Be careful: if the powder is to course, it will descend to the bottom of your product).
Add just a little bit of finely divided powder to the mixture and stir thoroughly.
You may also leave the eraser white, without any pigment.
Example 2:
Add a little bit of **fine sand** to the mixture and stir thoroughly.

Remember: too much pigment or sand will cause the final product to crumble!

Step 4

Pour the mixture from the 250ml paper cup, into a clean glass vial. If you want a multi-coloured eraser, share some of your mixture with your partner. Fill the vial to the brim and leave for a few minutes.

Step 5

Put the glass vial, with plastisol, in a preheated oven at 180° - 200°C at least for one hour. If the product turns yellow or even brown, degradation has started. Take your product from the oven immediately.
Switch off the oven and leave the erasers to cool down completely.
Remove the eraser by carefully pulling it from the glass vial and cut the top with a sharp knife.

Repeat this whole procedure and change the pigment to sand or vice versa.

EXTRA ACTIVITIES

Let students experiment with their second eraser and suggest the following:

- The mould, for producing an eraser, can be changed. Any material withstanding the heating process, up to 180°C, can be used. Moulds in the form of hearts, squares or spheres, used for normal baking, are ideal.
- Students may even add a few drops of essential oil in the second eraser for an authentic smell!

QUESTIONS/ANSWERS

1. Try to erase any pencil marks with the pigmented/white eraser.
   Is your product successful?

   The eraser should easily remove the pencil marks.

2. Can you compare your own eraser's abilities to that of a commercial eraser?

   There should be no difference between the homemade eraser and a commercial one.

3. Try to erase any pen marks, first with the pigmented/white eraser and then with the sanded eraser.
   Which product is successful?

   The eraser with sand, as an additive, should erase the pen marks better than the product without sand.

4. Do you think that modern erasers differ from your homemade erasers?

   The same ingredients are mainly used. Extra additives could be extenders, to make the product cheaper, different pigments and sometimes additives to give the eraser a pleasant fragrance.

BACKGROUND INFORMATION...

PVC is one of the most widely used materials in the world. The market sectors in South Africa include: rigid pipe and fittings, cable and wire coating, bottles, footwear, flooring, clothing and packaging. PVC-material, has come under severe attack, lately, because on degradation or burning it releases chlorine atoms detrimental to human health and the environment. Some European countries has totally banned PVC materials used for food and any other packaging.

PVC is a rigid, clear material and the growth in PVC use was stimulated by the introduction of **additives**. The use of additives started to provide a means of producing finished PVC products with literally any desired properties.
Additives can be classified as:

- plasticisers
- stabilisers
- pigments
- lubricants
- impact modifiers
- fillers
- extenders.

A **plasticiser,** compatible with the polymer, makes it flexible and enhances cross-linking of the material at elevated temperatures.

PVC degrades readily due to the effect of high temperature or environmental influences. Chlorine atoms released can form hydrochloric acid with moisture in the air. To prevent the material from degrading at high temperatures (e.g. in the oven) a **stabiliser** is used; it gives good heat stability. The stabiliser also has a lubricating and modifying effect on the material. If the stabiliser is omitted, the product will turn yellow on heating, indicating the start of degradation.

Both organic and inorganic **pigments** are used to give bright colours (e.g. think about the beautiful colours of a durable, protective PVC tablecloth). The coloured chalk is used as an inorganic pigment and does not have an effect on the physical abilities of the material.

Over the years, scientists and engineers have found ways to improve upon the existing polymer and developed properties to satisfied human needs. Modern erasers are no difference. Extra lubricants like vegetable oil, fillers like talc, and different other additives help to produce an essential article to make life easier!

6.2.5 Foamed polyurethane

Polyurethane is one of the most versatile plastic materials on the market and a variety of materials and products can be perfectly imitated by experimenting with polyurethane.

This specific experiment starts as part of a demonstration to show different ways to create a plastic product. It was changed into something creative by adding component A and component B together in an ice cream cone and then end with a foamed ice cream. When this experiment is combined with the experiment on liquid latex, the latex paints are ideal for painting the ice cream delicious colours!

The principle of a chemical reaction between two reagents that emits heat and the role of carbon dioxide in this reaction is discussed. This experiment also challenges the student to be creative and design products where the methods used can be applied to create useful products.

Subject specific outcomes

- Measure and mix the precise amounts of components A and B
- Observe the chemical reaction concerning the blowing agent and the foamed product
- Testing of the strength of the final product
- Discussion on the uses and applications of polyurethane
- Creation of new products with polyurethane foams.

Experiment 5

AIM:
Polyurethane is one of the most versatile plastic materials on the market and a variety of materials and products can be perfectly imitated by experimenting with polyurethane. Students will use a component A and B to produce a foamed polyurethane ice cream.

REQUIREMENTS:

APPARATUS	CHEMICALS
3 x 75ml paper cups 1 x stirring rod Pair of safety glasses Ice cream cone* Old newspapers* Apron Paper towels Old shoe box*	Chemical A Chemical B Acetone

*Items not provided

PREPARATIONS:
Time: 5 minutes

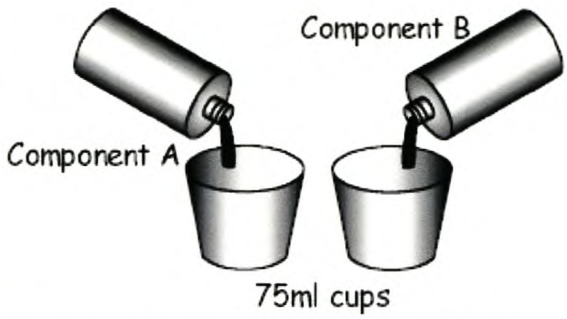
1. Cover the working surface with old newspaper.
2. The foaming reagents in an ice cream cone add excitement to this experiment. Cones are available at local grocery stores. Alternatively, use the extra 75ml paper cup provided.
3. The final product must be left to dry. Use an old shoebox, turn it over and cut out 50c holes, 15cm apart, on the bottom.
4. The cone(s) can be left on the shoebox to dry, and dripping/spilling of any foam is on the stand.

SAFETY PRECAUTIONS:

1. The chemical reaction between the two reagents generates heat, and can slightly burn your hand. Be careful!
2. Wear protective clothing or an apron because once the polyurethane gets on your clothes it is difficult to remove. Use acetone to clean your hands, if necessary.
3. Because of heat build-up, there can be a little explosion like soup in a cooking vessel! Wear the safety glasses.
   **There is one pair of safety glasses per 2 students; students doing the mixing should wear the glasses.*
4. **Work in a well-ventilated room. Do not** inhale any of the fumes released, while the chemicals react.

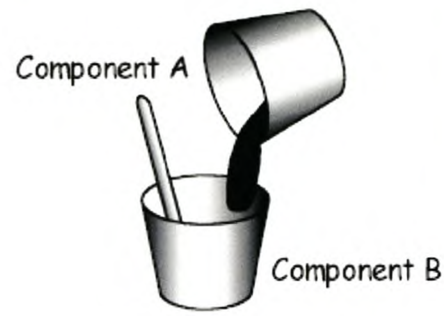
PROCEDURE:
Time: 5minutes

Step 1



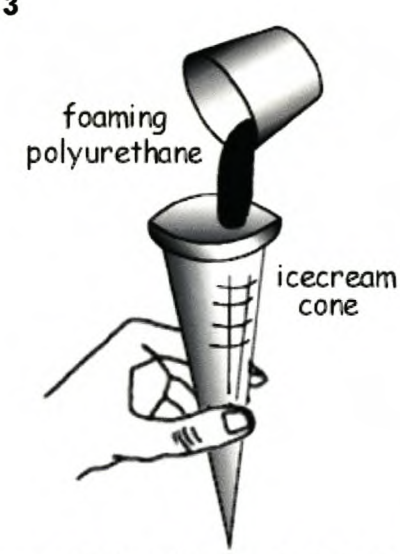
You have been provided with 40ml of component A and 40ml of component B.
Each student should measure approximately 10ml of component A and 10ml of component B in two different 75ml paper cups.
(Leave the other half of the container for later experimentation).
Clean the lids of the containers and close them immediately.
**If the lids get stuck, soak for a few minutes in warm water and open.*

Step 2



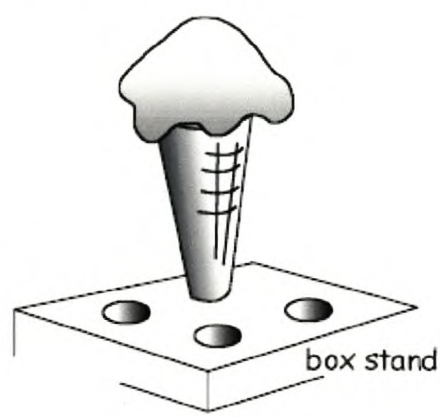
Add component A to component B or vice versa.
Mix the two ingredients thoroughly with the ice cream stick for 60 seconds.

Step 3



The moment the mixture starts to foam (even if it is not yet 60 seconds) pour the mixture into the ice cream cone.

Step 4



Put the ice cream cone on the shoebox stand and leave for at least an hour to dry.

Step 5
If the practicals on "Painting with Latex" and "Polymer Slime" are also done, the foamed polyurethane can be painted with different bright latex colours (like an ice cream) and the slime, also in brilliant colours, on top, makes it look quite tasty…!

Note: *The initial amount of component A and B can be increased for more foam or when the components get older.*

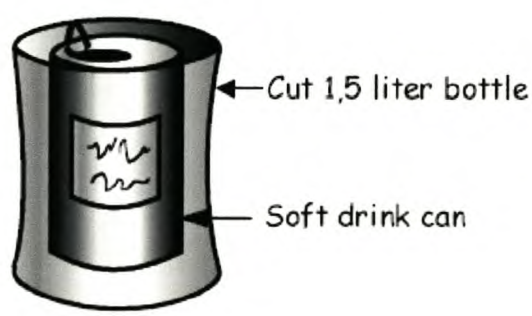
EXTRA APPLICATIONS

1. Creating with foamed polyurethane can be lots of fun and very creative! There should still be 10ml of component A and 10ml of component B left in the 50ml containers for each student.
   - Always work in a well-ventilated room, do not inhale the fumes, wear safety glasses and an apron.
   - Follow the procedures for foaming; this time in a 75ml cup.
   - Test the foamed polyurethane, after it has stopped foaming, when still warm and rubbery (not sticky!).
   - Try to sculpture a face from the foamed polyurethane mass and paint it with liquid latex paint obtained from the practical on "Painting with Liquid Latex"

2. Here follows another example (students should work in pairs).

   Producing of a lightweight rigid foam cooler box to keep a product at a cool temperature. The mould consists of a soft drink can in a 1,5 liter Coca-Cola bottle.

   - Always work in a well-ventilated room, do not inhale the fumes, wear safety glasses and an apron.
   - Cut the 1,5 liter bottle at the same height than the can. See sketch for the design.



- Mix equal quantities (10ml) of component A and component B in a separate paper cup and **before** it starts to foam, pour it into the bottle to cover the bottom. Be careful for any light explosions!
- Keep the can suspended above the bottom and wait for the foaming process to be completed. The foam expands and fills the cavity.
- After the foam has hardened, remove the mould, cut the top and sand it.

QUESTIONS/ANSWERS

1. What are the indications that a chemical reaction has occurred?

   Generation of heat (exothermic chemical reaction)
   Generation of a gas; blowing or foaming of urethane.

2. You started initially with 10ml of component A and 10ml of component B and ended with a product more than three times the original volume. How is this possible?

   *The isocyanate molecules react with water to form an intermediate product, which decomposes to release **carbon dioxide** acting as the blowing agent to expand the structure.*

3. Do you know of any other materials used to manufacture foamed products?

   Foamed polystyrene (show examples of foamed polystyrene cups or protective packaging material)

4. Name at least **five applications** of foamed polyurethane material in our daily lives.

   Sport shoe soles
   Sport mats
   Mattresses
   Car seats, steering wheels, vibration dampening on car floors
   Sound insulation in walls
   Carpet back
   Crash pads (arms and knees)

BACKGROUND INFORMATION...

The family of urethane foams is one of the most versatile members of the cellular plastics group, and is growing more versatile each year. Depending on the starting materials used, it is possible to produce a range of products from extremely strong soft flexible foams through to rigid foams.

Polyurethane can also be an elastomer, used in paints, fibers or adhesives. They just pop up everywhere, like the wonderful polyurethane spandex, a fibre that we use to make fabric that stretches for exercise clothing and the like. If you are sitting on a padded chair right now, the cushion is more likely to be made of polyurethane foam. In short, polyurethane is a unique material that offers the elasticity of rubber combined with the toughness and durability of metal and allows the engineer to replace rubber, plastic and metal with the ultimate in abrasion resistance and physical properties.

Polyurethane foams are prepared by the reaction of two chemicals: a di-alcohol (or polyol) and a diisocyanate. These two chemicals are provided as component A and B in this experiment. The "di-" prefix means: two alcohol molecules and two isocynate molecules are present in each molecule. Firstly the alcohol molecules react with the isocyanate molecules to produce a long chain – the polymer. Secondly the remaining isocyanates react with moisture to form an intermediate product, which decomposes to release carbon dioxide acting as the blowing agent to expand the structure. The chemical reaction is exothermic and produces heat.

By varying the amount of polyol and isocyanate, a wide variety of foamed products, from soft and flexible to hard and rigid, can be produced. Rigid foams differ from flexible foams in that they do not recover when deformed. Rigid foams have outstanding insulation properties, good compressive strength, and outstanding buoyancy characteristics. Applications are in such markets as construction, insulation, refrigeration, furniture and packaging.

6.2.6 Slimy Polymers

Colourful slimes sold in many toyshops and on bazaars, provide hours of fun to kids! This experiment provides a chance to work with the polymer, poly(vinyl alcohol), in combination with a borax solution that acts as the cross-linker in the chemical reaction to provide the slimy polymer.

Careful preparation, as mentioned in the teacher's manual, is essential to ensure the successful cross-linking of the chemicals. Questions on the appearance and strength of the final product directs the student to the principles of a water-soluble polymer material and the process of three-dimensional cross-linking of macromolecules. Various applications of polyvinylalcohol in our daily lives strengthens the importance of this practical experience.

Subject specific outcomes

- Measure and mix of poly(vinyl alcohol) and borax solution
- Use of colourant for the final product
- Explain the characteristics of the slimy product
- Discuss applications of poly(vinyl alcohol) in various fields.

Experiment 6

AIM: Colourful slimes, sold in many toyshops and on bazaars, provide hours of fun! This is your chance to make your own polymer slime!

REQUIREMENTS:

APPARATUS	CHEMICALS
2 x paper cups 2 x stirring rods Paper towels Old newspapers* 1 x rubber glove Zipper plastic bag	99% hydrolysed PVA powder Borax powder Tap water* Food colouring

*Items not provided

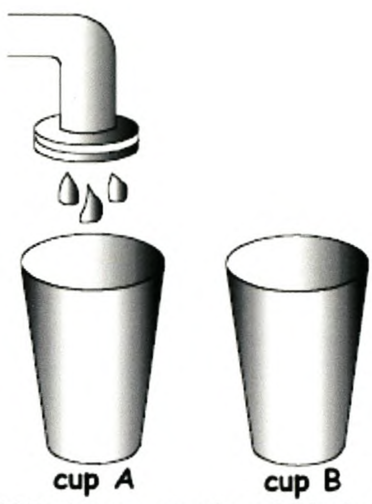
SAFETY AND PREPARATIONS:

Time: 30 minutes

1. Polyvinylalcohol is a water based polymer and safe to work with. Have a soapy solution ready to wash hands.
2. Wear protective clothing and a rubber glove while performing this experiment. Food colouring can temporarily stain the hands and spatter on your clothes.
3. Cover the working area with old newspapers.
4. Use a rubber glove when handling the final product.
5. Do not use a PVA solution or borax solution prepared well in advance.
6. PVA powder does not dissolve easily. Sprinkle small amounts of powder on the water and stir thoroughly. Students have to stir both solutions at least for 30 minutes before mixing any chemical solution.
7. The final mixture will stay in liquid form if too much borax solution was used; or it will take much longer to gel.
8. If the mixture does not gel at all, the chemicals or solutions are too old.
9. Any excess PVA solution must first be diluted with water and then flushed down the drain.

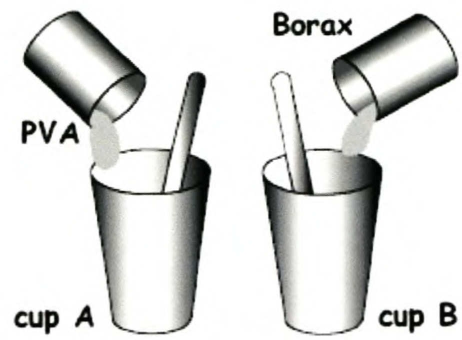
PROCEDURE:

Step 1



Pour 100ml tap water in a 250ml paper cup **(cup A)** and 100ml tap water in another 250ml cup **(cup B).**

Step 2

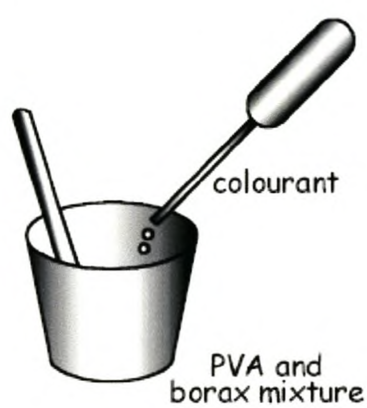


Divide the polyvinylalcohol (PVA) powder and borax powder between you and your partner. Add the PVA powder (4g) in small amounts to cup A and stir thoroughly. Add the borax powder (4g) also in small amounts, to cup B and stir thoroughly.

Step 3

Cover the bottom of a 75 ml cup with borax solution; a depth not more than 5ml. Add PVA solution to the borax solution (half of the cup).

Step 4



Put a few drops of food colouring in the mixture and start to mix.

Extra: Perfect your painted polyurethane ice cream with a colourful ('delicious') PVA sauce on top!

QUESTIONS/ANSWERS

1. Touch the slimy polymer. What does it feel like and give a reason for your answer?
   The polymer feels wet. Water molecules are trapped between the cross-linked polymer molecules.

2. What happens to the final product if you leave it for a few on a flat surface? Give a reason for its behaviour?
   It will start to flow or ooze because over time this weird material shows a decrease in viscosity – the molecules have time to untangle, and will spread out on the surface. If the material is left exposed to air, the molecules will vapourise and it will dry out.

3. Try stretching the slime: first very slowly and then quickly. What is the difference?
   With slow stretching, the molecules will (up to a point) start to untangle. With a sudden external force on the material, it will break – the molecule chains have no time to move and the chains will break.

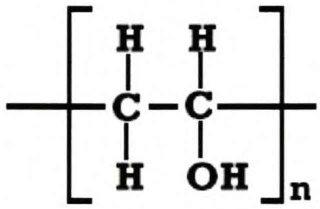
4. This versatile polymer finds applications in various fields. Can you suggest any major application areas?

   Adhesives
   Paper coating
   Textiles
   Building products

BACKGROUND INFORMATION…

Polyvinylalcohol is a polyhydroxy polymer and a water-soluble synthetic resin. The acronym PVA is used for polyvinylalcohol but it causes confusion with the polymer: polyacrylate. Therefore PVOH is a better term for polyvinylalcohol.

The solution of polyvinyl alcohol powder in water results in long polymer chains consisting of thousands of vinyalcohol units (monomers) linked together to form the polymer or macromolecule. The structure of the polymer can be represented by the following chemical formulae:



The long polyvinylalcohol chains in solution are entangled like spaghetti in a bowl of water. This contributes to the 'thickness' of the water; we say the mixture is viscous.

The borax solution acts as a cross-linking agent. The borate ions cross-link with the alcohol groups of different polyvinylalcohol chains creating one giant 3D cross-linked polymer. Water molecules are trapped between the spaces of the cross-linked material leaving it with a wet feeling. The mixture barely flows at all and becomes more viscous with time. Slow pulling will give the spaghetti-like molecules time to flow and result in a longer article. A quick pull will result in high stress and cause the molecule chains to break.

Adhesive formulations of polyvinylalcohol are used in the manufacture of paper board, sealed cases and cartons, book padding and solid fibre board. Polyvinylalcohol is used as a blend with any natural or synthetic textile fibres. It has good strength characteristics and an attractive feel in fabrics. It is widely used in emulsions for paints, films for packaging and in many cosmetic applications!

Chapter 7

Evaluation

7.1 Multimedia programme

Secondary schools in the Western Cape participated in the evaluation of the multimedia programme created for this project (see Addendum). Evaluation took place from September 2000 until November 2001. Schools that nurture a positive attitude towards the use of technology were selected. The student sample selected for this evaluation comprised Grade 10 and 11 students.

It was important to evaluate this programme for the following reasons:

- To provide feedback to the author while the software was in the final stages of the development phase
- To evaluate whether students could relate to the information presented and link new knowledge to their own science knowledge
- Identify whether the information filled 'weak points' in the science knowledge of the students
- Obtain information on the students' current knowledge of polymer science
- Monitor effective learning
- Identify problem areas such as inadequate explanations or instructions
- Identify language, spelling and technical problems in the programme.

Certain assumptions regarding academic background and technological skills were made for the evaluation to be considered valid. As mentioned previously it was assumed that the students had scientific knowledge of the following:

- the periodic table and its elements
- atoms consisting of protons, electrons and neutrons
- spatial orientation of an atom or molecule
- orbitals and valency
- molecules produced from covalent or ionic bonds
- attraction and repulsion forces
- basic chemical reactions between atoms, ions and molecules
- energy involved in chemical reactions
- writing and reading chemistry “language” according to the IUPAC convention.

The evaluation was done with the assumption that the participants had the following technological skills:

- able to launch a compact disk from the CD-ROM of a computer
- able to use a mouse for navigation through software
- knew how to use soft buttons to access hypermedia information and to navigate through a software programme.

A questionnaire was chosen as evaluation method because information from a relatively large group of participants could be obtained. The questionnaire consists of checklist questions, four point value list questions (Likert scale) and open-ended questions, where the teacher and student had the opportunity to give feedback on any aspect to improve the use of the programme. Free text responses provided a platform to give an overall opinion on the multimedia programme.

Students were told beforehand why the information was being collected and were asked to reply honestly. If a response was negative it was just as useful as a positive opinion. No time limit was given and respondents could complete their evaluations in their own time. The participants were given the option whether to put their names on the questionnaire or not. This was due to the fact that some students might lack confidence voicing their opinions to the evaluator whereas others might only take the responsibility of taking part in the evaluation seriously if they had to put their name to their opinion.

Evaluation was limited to only the most important questions regarding content, layout and technical issues and was completed after the students had a chance to work through the software programme.

7.1.1 Questionnaire and Statistics

The following tables contain different **statements** and the **percentages** of positive and negative answers and/or opinions.

Table 1

Statement		Yes	No
1.1	Instructions to launch the programme are clear	95%	5%
1.2	Headings clearly indicate the exact position of the user in the programme.	100%	0%
1.3	A Help Files section helps to understand navigation through the programme.	55%	45%
1.4	Accessing extra information via the bold or yellow buttons is obvious.	95%	5%
1.5	Technical instructions on the Questions and Answers section can easily be followed	80%	20%
1.6	Instructions to proceed from one screen to the next are clear	90%	10%
1.7	The layout of the programme captured my interest and prompted me to learn more about plastic materials.	100%	0%
1.8	The background distracts attention from the content material	5%	95%
1.9a	I could differentiate between plastic materials before I worked through this programme	5%	95%
1.9b	After completion of this programme, I can differentiate between plastic materials	100%	0%
1.10	The Questions and Answers section pointed out the 'weak points' in my knowledge of plastic materials	85%	15%
1.11	Have you ever tried to access information on polymers science from the INTERNET or library?	5%	95%

Table 2

Statement		Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree
2.1	Navigation through the programme is user - friendly	90%	10%	-	-
2.2	Navigation backwards to the original screens is easy	65%	20%	15%	-
2.3	The polymer science content links to already-known science knowledge	90%	10%	-	-
2.4	The programme adds value to my understanding of the vast world of science	100%	-	-	-
2.5	Graphics and pictures add value to the theoretical content	100%	-	-	-
2.6	Animations add value to the theoretical content	75%	-	25%	-
2.7	Content has relevance to my life and immediate environment	100%	-	-	-
2.9	Replay buttons are necessary to help understand chemical reactions	75%	25%	-	-

Statement		Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree
2.10	The content of the programme is too difficult to understand	-	8%	22%	70%
2.11	An interactive multimedia programme is a better option for me to gain science information than a lecture in a classroom	80%	20%	-	-
2.12	This programme inspires me to learn more about the world of materials around me.	100%	-	-	-

Table 3

Open-ended statement		Answers to choose from	%
3.1	The sound used in the programme is:	Irritating	30
		Funny	43
		Used effectively	50
		Too long	-
		Too short	-
3.3	Font used throughout the programme is:	Unreadable	-
		Funky (modern)	33
		Formal	-
		Perfect	100
3.2	The size of the font is:	Too small	-
		Too big	5
		Perfect	95
3.4	Images used for the backgrounds are:	Too bright	-
		Too dull	-
		Overwhelming	-
		Distractive	7
		Attractive	93
3.5	Colours used for the headings are:	Too bright	-
		Too dull	-
		Overwhelming	-
		Perfect	100
3.6	Colours used for the text are:	Too bright	-
		Too dull	-
		Overwhelming	-
		Perfect	100
Teachers only…			
3.7	The content of this programme fits in with the following subject areas:	Science	100
		Technology	100
		Entrepreneurial skills	25
		Environmental studies	30
		Other	-
3.8	The standard of this programme is best suited for:	Grade 9	-
		Grade 10	100
		Grade 11	100
		Grade 12	10

Open-ended statement		Answers to choose from	%
3.9	This programme can be used as a:	Teaching tool	75
		Source of information on plastic materials	100
		Self-study programme for students	25
3.10	This programme will:	Save me time to search for relevant information on plastic materials.	100
		Inspires me to use this available information as part of the science curriculum	95
		Stimulates me to be more aware of modern materials and technology	100
3.11	The following outcomes are addressed:	The development and use of science process skills	-
		The development of scientific knowledge and understanding	100
		The development of an appreciation of the relationship and responsibilities between science and society	60

7.1.2 Analysis and feedback

Free text responses of the participants provided valuable information not only to analise the statistics in paragraph 7.1.1 but also to give feedback on critical issues around this programme.

Technical Aspects:

Launching the programme via the CD-ROM gave initial problems to participants not familiar with the more technical aspects of a computer. This problem was overcome by programming an autorun.ini file, which forces the software to run automatically when launched. No problems were reported after this improvement.

Help files are essential to the successful explanation of any software programme. **Help Files** in this programme were initially only accessible from the main menu. This was changed after the first two evaluation sessions so that access could be from each chapter. It is clear from the statistics that more than half of the participants needed some or other help from the Help Files.

Navigation of a software programme is the most important aspect to be evaluated. Without a proper navigation system or user-friendly navigation instructions or buttons, the user will get lost and loose interest. A very high percentage (90%) of the participants indicated that navigation through the programme was user-friendly. It is easy to proceed from one screen to the next. A few mentioned that they had to read the Help Files first before they understood the navigation system (the 10% in table 2 question 2.2?). Problems arose when a user had to go back to previous screens. The button of the previous screen is always available, but most of the time the user can not remember the name of the previous screen. A solution was to increase the amount of "Go Back" buttons in the programme as an alternative option. Problems in the navigation of the Questions and Answers section can be attributed to the fact that the layout of this section is different from the rest of the programme.

Layout:

The interesting layout of the programme immediately captured the interest of the participants. A small number (5%) indicated that the **background** was initially too distractive (Table 1, question 1.8 and Table 3, question 3.4). The majority commented that the background contributed to the overall polymer science 'look and feel' of the programme and enhanced the learning process.

The first group that evaluated the programme reported that loading of information in the Historical Timeline sections was too slow. A better option was to program the information to load concurrently and not sequentially.

All the participants indicated that the use of **colours, graphics, pictures and the type of font** contributed to the success of the programme.

Some of the users indicated a loss in concentration the moment an animation starts playing while they were still reading text (table 2, question 2.6). A valid option, to accommodate the slower reader, would be to provide more buttons, by means of which the user could start an animation after he/she had read through specific text. More replay buttons partly solved this problem.

The sample group was divided on the issue of **sound**. The free text responses showed that although sounds used repetitively during the Questions and Answers section became irritating, sounds used for buttons throughout the rest of the programme were perfect. A good choice would be to program an option whereby the user is allowed to decide whether he/she wants to hear sound or not. This has not been done yet.

Content:

Only a small percentage of teachers and students indicated that they have previously used the INTERNET or a library to access any information about polymer science. All the participants indicated that the programme added value to their science understanding and that the content had relevance to their own lives and the environment.

It was expected that a low percentage of participants would initially know the difference between different plastic materials. The Questions and Answers section pointed out these 'weak points' and users could go back to the appropriate information.

From the teachers' evaluation, the programme is most suitable for Grade 10 and 11, although early Grade 10's will have problems with some of the scientific concepts and should find the content too advanced. This notion was confirmed by the statistics in Table 2, question 2.10 and some of the free text responses from evaluation sessions early in the academic year.

Teachers overwhelmingly indicated that a multimedia programme like "Fun with Polymers" will not only save them time in searching for relevant information on plastic materials but also stimulate them to be more aware of modern developments in the world of materials and technology.

The content of this programme is suitable both in the fields of science and technology and, to a lesser extent, in the entrepreneurial and environmental fields. Although students indicated that they would rather be taught science by means of a multimedia programme rather than a lecture, teachers indicated a preference for the programme as a teaching tool and a source of information on plastic materials.

7.2 Practical programme

Evaluation of the primary school level practical programme focused mainly on two aspects: evaluation to determine whether the participants experienced effective learning and feedback from presenters of the programme to streamline the practical activities.

Evaluation data was obtained from two sources:

- the MTN Sciencentre, Sunzone Centre of Stellenbosch University, where a programme on synthetic polymer materials is currently being presented (since September 2000 during the school holidays)
- TechnoX Science Festival at SASOL, Sasolburg, where this practical programme was presented to primary (and secondary) schools during August 2001.

The sample selected for this evaluation was Grade 6 and 7 students. Schools were not specifically targeted to participate in this programme. Bookings to attend a practical programme were done on an ad-hoc basis. A practical session could consist of either 20 children from an individual school, or an open session consisting of children from any school present at the Sunzone Centre on a particular day. This demography provided the opportunity to evaluate the practical activities on a broader front, because participants were from different backgrounds and skills. Teachers of these different groups also added their individual opinions to the evaluation and contributed to changes made in procedures of specific activities.

Reasons for the evaluation of the primary school practical programme are:

- To evaluate whether effective learning takes place.
- To evaluate whether the content and presentation of the practical activities are suitable for the level of students chosen.
- To identify problem areas in the execution of the practical activities. This includes e.g. quantities of chemicals used , the use of apparatus, practical methods applied or the structuring of the groups that work together.
- To identify students' knowledge of plastic materials at this level.

The practical activities for primary schools focus on the concept to link a playful environment to basic science principles. Basic skills required to perform these activities include the ability to:

- do basic mathematical calculations
- handle a paintbrush, scissors, pencil

- measure and mix of precise amounts of chemicals for a chemical reaction
- observe and notify the results of a chemical reaction
- identify different materials in the immediate environment
- be creative.

(The specific outcomes of each practical activity are mentioned in chapter 6).

A questionnaire for a pre- and post testing of the participants was chosen as a viable method to assess the extent to which this educational intervention had an impact on 'student' learning. This was not just a performance measure of the number of 'correct' responses of the participants, but determination of the manner in which the practical activities have caused an alteration in their responses even if only on a primary school level.

A practical session consisted of five practical activities:

- Identification of plastic materials
- Painting with liquid latex
- Creating a poly(vinyl chloride) eraser
- Foaming with polyurethane
- Working with poly(vinyl alcohol) to make a slimy polymer

The sixth activity on recycling, was left to teachers to experiment with in their own time.

Each participant received an A4-paper with the same questionnaire on both sides, marked questionnaire 1 and 2 . They were told beforehand why the information was being collected and were asked to reply honestly. If a response was negative it was just as useful as a positive opinion. The participants were given the option whether to put their names on the questionnaire or not. They had to complete questionnaire 1 before they started the practical activities and questionnaire 2 after they had completed the session. No time limit was given and respondents could complete their evaluation and practical session in their own time.

7.2.1 Questionnaire and Statistics

	Questionnaire for Pre and Post Testing
1	Do plastic materials play and important role in our lives? Where? …………………………………………………………………………………………
2	Can you suggest possible ways to differentiate between different plastic materials: …………………………………………………………………………………………
3	Where do plastic materials come from? …………………………………………………………………………………………
4	Which element on the periodic table is the core element around which the chemistry of life (and the plastic industry) evolves? …………………………………………………………………………………………
5	Can you suggest any chemical process by which plastic materials are created? …………………………………………………………………………………………
6	What do the following symbols represent?  ………………………  …………………………
7	Who are the biggest culprits of pollution in our environment: a) human beings b) plastic materials …………………………………………………………………………………………

Statistics on the questionnaire were as follows:

	Pre Testing		Post Testing
1	All the students (100%) indicated that plastic materials play a very important role in their lives, and that they touch and use these materials repeatedly, on a daily basis. Only 35% of the students indicated correct applications of plastic materials mostly in and around their homes.	1	The amount of students that correctly indicated applications of plastic materials increased to 92%. Examples of applications now included items outside their immediate environment and some industrial applications.
2	Only 8% of the students could suggest possible ways to differentiate between different plastic materials, like bending or identification by transparency. Individuals mentioned the fact that they had melted plastic materials and tried to remould it. All of the teachers indicated that they had no or little exposure to information or access to experiments on polymer chemistry and expressed the need to implement a programme on plastics.	2	86% of the participants could mention at least two ways by which to differentiate between different plastic materials; 75% mentioned three ways to differentiate and identify plastics.
3	Many students (> 65%) knew that oil and coal (but not natural gas) are the raw materials to produce plastic materials from. Some of them mentioned SASOL as a company producing plastic products.	3	More than 90% of the students knew that coal, oil and/or natural gas are the raw materials for the production of plastic materials. (Some of them also correctly mentioned chemicals, used in the practical activities, to produce a plastic material)

Pre Testing		Post Testing	
4	Only 5% of primary school participants knew that the carbon atom is important in the building of plastic materials. (Theory around the carbon atom is introduced in Grade 9, hence this could have been a wild guess!)	4	After a demonstration where the giant molecule or polymer concept was physically demonstrated, 94% of them remembered that carbon is the key element in building macromolecules.
5	None of the students had an idea of the chemical processes used to manufacture plastic articles. Again, individual students indicated that SASOL had something to do with manufacturing of plastic materials.	5	All the students could now, from experience, indicate at least one method of creating a plastic material; either latex that gels in contact with air, foaming of polyurethane reagents or the cross-linking of molecules in a PVOH- and borax solution mixture.
6	12% of the participants had seen the international codes that identify different plastic materials. Those who recognised the codes did not know what they stood for.	6	All the students knew that the codes indicate an international logo to differentiate or identify plastic materials. 85% identified both codes correctly, even though nr 1 was linked to a Coke bottle as an example!
7	82% of participants indicated that human beings are the culprits in the pollution of our environment and not the material itself. This was sometimes reason for heated debates!	7	90% of participants indicated that human beings are the culprits in the pollution of our environment and not the material itself.

7.2.2 Analysis and Feedback

The goals for the pre- and post testing questionnaire were met. The pre-testing clearly shows the lack in basic knowledge about plastic materials, whether it is the identification of a plastic article or the origin of synthetic polymers. Effective learning took place through practical experience.

Students had minimal problems in interpreting and carrying out the different activities. Basic methods to identify common plastic materials were learned. Several additional plastic articles could quickly be identified with the identification logo chart as reference. Correct identification brought them into contact with the issue of recycling and participation in the activity on recycling. Students learned that they can create everyday articles, like erasers and rubber, if they had the correct chemicals available. Numerous applications of the plastic materials they used and created were pointed out.

Valuable feedback and questions from presenters of the practical activities at the MTN Sciencentre resulted in answers and changes reported in the table below:

Feedback/Questions	**Response**
Identification of plastic materials:	
Students have difficulty in performing the density test.	The test is simplified to only three densities being used: $\rho >$ water, $\rho =$ water and $\rho <$ water.
There is a risk factor involved when children work with fire while performing the flame testing.	The activity is changed to a teacher's demonstration, where the students have to notify all the chemical changes that occur during a flame test.
The initial flow diagram, to identify foreign plastic materials, are too difficult to follow or 'read'.	The flow diagram is simplified to only the materials used in the practical activities and includes some well-known materials like Nylon and Perspex.
Painting with liquid latex	
Paint brushes become clogged with liquid latex.	The principal demonstrated here is that liquid latex gels when in contact with air or a neutralising agent, like ascetic acid. Paint brushes with natural fibre bristles are substituted with brushes with nylon bristles. Much easier to clean.
Creating a PVC eraser	
The final product is too brittle.	The amount of PVC powder used in the formulation is decreased. The kind of pigment and the amount of pigment also play a role. Too much pigment leaves the product to be brittle. Experiments with pigment, that is not inert, also left a brittle product.

Feedback/Questions	Response
The final product appears to have a pasta inside.	The amount of plasticiser used in the formulation is decreased. The final product are left in the oven to cool down overnight.
Degradation ruined the final product	A balance between a high temperature and time spent in the oven is essential for the correct final product. A tempearture > 200ºC can easily ruin the product, therefore the product is baked at 180ºC and left in the oven for a longer period.
Foaming with Polyurethane	
There is no chemical reaction between the two components used.	Fresh components react immediately. The older the components are, the longer it takes to foam. The presenter must test the reaction before the practical activity.
Some of the final products is solid and others are rubbery.	Equal amounts of the components will result in a solid product. If one component is in access, a rubbery product will be produced.
Working with Poly(vinylalcohol) – slimy polymers	
There is no chemical reaction between the two components used.	Fresh components react immediately. Components prepared more than 36 hours beforehand will not react. Poly(vinylalcohol) granules are used instead of ready made solutions obtained from painting companies. Mixing of the granules with water is incorporated in the practical activity.

Feedback/Questions	Response
Poly(vinylalcohol) granules do not dissolve in water.	Poly(vinylalcohol) granules take a long time to dissolve in water. Participants must start with this activity at the beginning of the practical and be reminded to stir the mixture thoroughly at 10 or 15 minutes intervals.
The mixture is too water or too solid.	It is essential to prepare and add correct amounts of reagents. Too much borax solution will end in the final product to be too watery and too much poly(vinyl alcohol) solution will end in a solid product.
In General	
▪ More **background information** on the chemicals and plastic materials, used during the practical activities, are incorporated on request of teachers. ▪ **Extra activities** are added to each practical for developing entrepreneurial skills and to have more practical applications.	

Picture next page: Primary school students at the MTN Sciencentre, Century City, Cape Town


Polymer Science
What is a polymer?

Conclusion

The design and implementation of this project on synthetic polymer materials resulted in **two major observations**:

- Enthusiasm of both primary school and secondary school students and teachers to experience the reality of their environment in the classroom.
- The need of teachers/lecturers to have access to quality scientific programmes, combined with easily obtainable chemicals and apparatus to implement in their own science curriculums.

Recommendations and feedback, both from students and teachers, were the incentive to expand this programme not only to be a multimedia programme on compact disk but also to be a practical experience both on secondary and primary school level. The strength of this programme lies unequivocally in the fact that plastic materials surround us and will be here for the rest of out lives! A programme on synthetic polymer materials is therefore relevant and essential. Effective teaching or learning and exposure to practical applications will ensure the knowledge to solve future problems arising from our ever-increasing demand on environmental resources.

The objectives, set out at the beginning of this project, were met. Accurate and adequate information on synthetic polymer materials are available. Correct answers are given to frequently asked questions about plastic materials. These answers are not only available from the multimedia programme but are also acquired from hands-on experience working with plastic materials during practical sessions. Both the multimedia programme and the practical experiments stimulate the student to learn and read more about the vast world of material science around them. This programme contributes to effective teaching by providing the teacher/lecturer and learner with a correct and relevant resource on plastic materials.

Recently Curriculum 2000 has changed to Curriculum 2005, but the emphasis on Outcomes-based Education has not changed. "Fun with Polymers" is still perfectly suitable for a learner-centric education environment where the learner takes responsibility for his/her own learning process. The programme adds to the concept-based instruction principle where students use skills and processes for constructing meaning and solving problems.

Technology as a tool to access knowledge is part of the presentation of this programme. The use of a computer makes available a variety of information on a compact disk and in more advanced form the INTERNET. To launch a programme like "Fun with Polymers" on the INTERNET gives rise to problems like speed and downloading time of information, security and the immediate contact with an enormous field of information sometimes totally irrelevant to the process of learning. Only when technology is used as a tool that causes students to think and apply concepts from the curriculum, learning is improved. Therefore it is, from the author's point of view, more effective and practical to expose learners to a multimedia programme on compact disk than 'loosing' them in the world of cyber space, trying to find their way to acquire information.

A **blended learning process** that encompasses technology, electronic learning, multimedia programmes, poster presentations, practical experiments, discussions and field trips, is by experience **effective learning**. This process is never static and continues to change through ongoing evaluation and feedback from learners and teachers, and changes in the world of science.

As a final comment on this project: using only science and technology to make our world a better place is accurately summed up by a quote from William Golding:

"Our humanity, our capacity for living together in a full and fruitful life,
does not reside in knowing things for the sake of knowing them
or even in the power to exploit our surroundings.
At best these are hobbies or toys – adult toys.
Our humanity rests in the capacity to make valued judgments and ,
unscientific assessments, the power to decide that this is right, that is wrong,
this is ugly, that is beautiful, this is just, that is unjust.
Yet, these are precisely the questions 'Science' is not qualified
to answer with its measurement and analysis.
They can be answered only by the methods of philosophy and the arts.
We are confusing the immense power, which the scientific method gives us,
with the all-important power to make valued judgments,
which are the purpose of human education[31].

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Presentations

The concept of Polymer Science for secondary schools in Southern Africa and the completed program "Fun with Polymers" were presented at the following conferences:

1. Paper presented at the 6^{th} International Conference on Chemical Education in Africa, Accra, Ghana, July, 31^{st} to August, 4^{th}, 1995.

2. Paper presented at the Fourth International Conference on Frontiers of Polymers and Advanced Materials, Cairo, Egypt, January, 4-9, 1997.

3. Poster presentation at the International Conference on Macromolecules, Stellenbosch University, Stellenbosch, South Africa, March, 22-24, 2000.

4. Paper presented at the 16^{th} International Conference on Chemical Education, Budapest, Hungary, August, 5-10, 2000.

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Addendum

I. The following schools took part in the evaluation of the multimedia programme:

Bridge House Private School, Franschhoek (50 students)

College of Science and Mathematics, Bergvliet, Cape Town (30 students)

Boys High School, Paarl (40 students)

Paarl Gimnasium Hoërskool, Paarl (30 students)

Nederburg, Sekondêre Skool, Paarl (30 students)

Abbott's College, Claremont, Cape Town (20 students)

II. Primary school students, from the following schools in the Western Cape, took part in the evaluation of the practical programme. The programme was presented during the school holidays, from September 2000 until September 2001.

Hermanus Primary

Swartland Laerskool

Camps Bay Primary

Milkwood Primary

Kenridge Primary School

L R Schmidt Primary School

Koeberg Primary

St Pauls Primary

Muizenburg Primary School

Worcester Primary School

Heathfield Primary School

Silver Stream Primary School

Bellville-Noord Primêr

The following primary school students took part in the evaluation of the practical programme at the TechnoX Science Expo SASOL in August 2001:

Sasol Secunda Primary School

Tsoaranang Primary School, Sharpville

SS Paki Primary School, Vredefort

Fakkelskool, Sasolburg

Mophate Primary School, Bothaville

III. The multimedia programme "Fun with Polymers" will be implemented in 2002 at the following institutions:

- Bridge House Private School, Franschhoek as part of the Grade 10 science curriculum
- Cape Town Technikon, Department Chemical Engineering and Department of Plastics Technology as part of first year subjects on the plastic industry.