3D VISUALIZATION SKILLS INCORPORATION INTO AN UNDERGRADUATE BIOLOGY COURSE

by

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Dedication

This publication is dedicated to the whole of my family.

"Give to the world the best you have, and the best will come back to you" (Author unknown).

Preface

This thesis represents the original work of the author, carried out in the School of Life and Environmental Sciences and School of Education, University of Natal, Durban, South Africa, under the supervision of Prof. Alan Amory and Mr. Mike Graham-Jolly. It has not been presented for any other degree or diploma in any institution. Where use has been made of the work of others, it is duly acknowledged by means of complete references in the text.

Joseph Osodo

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Abstract

Current trends indicate that the population explosion and invasion of information technology, particularly in developing nations, are likely to overwhelm education systems and policy makers, educators, researchers and therefore the community faces enormous challenges. Also, many graduates of various levels and disciplines appear unable to practically apply their knowledge in problem solving situations.

In an attempt to achieve and maintain high educational standards, many nations are devoting substantial proportions of the gross domestic product toward educational endeavours. However, few systems are adopting modern education practices that intrinsically motivate and engage learners, and are at the same time flexible enough to consider students' aspirations and interests. It is argued that such systems would make learning more relevant, meaningful and enjoyable to the learners and are bound to improve exit performances. In such a system, the role of the teacher is that of a facilitator, and not instructor.

Constructivism, a philosophy which holds that knowledge is actively constructed by learners through learning, is regarded as promising to provide a long-term solution to many educational problems since its underlying principles are argued to be holistic.

It has become imperative that technology in general, and the computer in particular should play a role as educational tools as these have capabilities that could be designed to

make learning relevant and interesting to learners.

It is argued that its use within constructivist approaches and curriculum considerations would increase learner abilities. An eclectic approach to curriculum design is advised for success in this endeavour. Since computers permeate most aspects of our lives (directly or indirectly) their inclusion in teaching and learning situations must become a reality.

This project is focused on underscoring the fact that computer based education (CBE), under constructivist philosophy, can provide solutions to problems brought about by extreme interpretations of the deductive or traditional teaching approach. Particularly, it attempts to show that use of three-dimensional (3D) visualizations could significantly aid comprehension and perception of, among other units of discourse, cytoplasmic structure, geo-referenced graphical data, and the understanding of spatial relationships. This is a technique that has, in the recent past, received little attention and no extensive educational research has been carried out with the aim of perfecting it.

Recent research carried out by members of the Biological Pedagogy (Bioped) research group identified conceptual problems in learners regarding biological processes such as photosynthesis and respiration. Having established that the misconceptions in learners were attributable to their lack of visualization ability, the first part of the project involved identifying some of the specific visual problems.

A qualitative research approach was used to ascertain from university lecturers what convictions, beliefs and experiences they had had with their students that related to use of visualization skills. Skills most required included interpretation of 2D and 3D structures as well as their rotation in space.

A survey was also carried out among Cell Biology first and second year students of the School of Life and Environmental Studies in order to precisely determine aspects of three-dimensionality and visual skills suspected to cause conceptual difficulties. Quantitative data analysis showed that the most deficient skills in the learners included pattern folding (projecting 2D material into 3D objects), orientation of form (identifying 3D objects that are oriented differently) and rotation (identifying 3D objects from top and front views). These findings corroborated qualitative analysis of lecturers opinions and convictions.

An educational computer game was designed with the aim of ameliorating these problems. The game consisted of 3D scenes where puzzles related to the skills mentioned above needed to be solved. It was recommended that visualization skills should be incorporated into the biology curriculum for all undergraduate students within the first year of the course.

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CHAPTER ONE

1. Objectives of the study and thesis outline

Prior (unpublished) research conducted by the Bioped Research Unit (School of Life and Environmental Sciences, University of Natal, Durban, South Africa) has identified that many undergraduate students experience problems relating to visualization. This project focused on the identification of specific three dimensionality and perceptual weaknesses in learners, with the aim of proposing solutions to the problems. Since the visualization skills are applicable to other disciplines, educational standards could consequently be improved by the inclusion of specific learning tools that foster the development of 2D and 3D visualization.

In order to propose the inclusion of 2D and 3D perceptual skills into the biology curriculum, the main objectives of the study were to:

(a) identify particular visualization skills learners require in order to learn effectively,

(b) examine the influence of cultural orientations on attitudes, experiences, exposure or interaction with (virtual) environments and how this could affect perceptual skills,

(c) assess the viability of incorporating visualization skills (as a separate course) into the undergraduate biology curriculum to enhance and improve learner skills and exit outcomes, and

(d) design and development of an educational game aimed at training learners in the use of three dimensionality and general problem solving skills, for instance, visualization of cytoplasmic structure and spatial organization.

Materials and methods used to achieve the stated objectives included:

(a) collecting information from experts (university lecturers) about their experiences, convictions and opinions on 3D visualization problems that learners have (interviews),
(b) collecting information from lecturers about their opinions on viability of introducing special separate visualization classes (interviews),
(c) observing learners from various socio-cultural backgrounds with an aim of collecting information about visualization problems or attitudes and experiences in using computer generated visual graphics, and
(d) carrying out three dimensionality and visual tests (questionnaires) on learners to identify particular problems that would inform the development of a CBE software.

Chapter one presents a review of literature on modern educational theories, educational technology in general, use of computers in the classrooms, discusses visualization skills as problem solving tools, CBE and curriculum frameworks. Chapter two describes convictions and experiences of academics regarding use of visual skills in teaching and learning and assessment of 3D visual skills in learners.

Chapter three discusses various concepts and considerations of games and educational gaming. In chapter four, the design of an interactive educational game (Dark Light) is discussed. In the final chapter, conclusions and recommendations are drawn on the basis of the research undertaken in the project.

2. Literature review: Introduction

Since technology is rapidly embracing various aspects of our daily activities, many countries have dedicated a lot of resources to education in an effort to incorporate it into the systems technology. However, the innovative use of computer technology in educational systems as a tool for teaching and learning is not clearly understood. Also, while technology is available in the well-developed countries, little funding or support is provided for such development in the less developed countries. Awareness, especially in the use of computers in education is lamentably low in the less developed countries as compared to the developed ones.

Worldwide, education appears to be in crisis. The ability of existing educational approaches to deliver knowledge appears unable to adequately assist learners to acquire skills and values appropriate to a rapidly changing world. These concerns are stimulating growth in the application of modern educational technology. There is evidence that a change is taking place that involves placing students (and technology), rather than instructors (and curricula), at the centre of educational practice (Greening, 1998).

In an examination of how using computer tools can alter education fundamentally, House (1979) suggested that successful integration of instructional technology (IT) in schools requires awareness of role of the teacher and the existing curriculum. This is because different curriculum considerations imbedded in individuals or groups of people influence their educational practices. The issue of contention here is that teachers ought to change their general instructional approaches of monopoly and rigidity to more open models that would give the learners considerable control and choice over their learning endeavours in an effort to improve educational standards.

In South Africa, as well as in other developing nations, use of computers in education is minimal even though the trend is changing to accommodate more widespread use of computers. In 1994, only one country in sub-Saharan Africa, South Africa, had direct access to the Internet. At the end of 1996, only 11 countries had local access, but by May 1999, only Congo (Brazzaville), Eritrea and Somalia were still without local Internet services. However, both Congo and Eritrea have recently announced plans to establish services. Ghana alone has three private Internet service providers (Jensen, 1999). In Kenya, for instance, an educator (university professor) acknowledged the fact that computers have become a necessity, expressing concern and disappointment that most educators themselves are computer illiterate. According to him, institutions have to embrace information technology if they are to survive in the 21st century.

"... by the year 2020, knowledge will be doubling every 73 days ...we must therefore start planning for the curriculum of the next century..." (Daily Nation, 1998).

Imminent redundancy of the textbooks currently in use is foreseen and teaching methods that currently predominate could be obsolete. Schools of the next century would be "schools without borders" (Daily Nation, 1998).

Underwood and Underwood (1990) suggest a number of assumptions underlying the assertion that computers can be used for educational benefit. The first is that educationists, parents and society in general would like to see the effective use of new technology in the classroom. Although many people are apprehensive about computers, they are also interested in the machine and acknowledge its power. The second assumption is that not all classroom use of new technology is beneficial, often because of the paucity of training for new and serving teachers in the more fruitful uses of the machine. Thirdly, by using the computer as a tool, it becomes both an amplifier of human capabilities and a catalyst to intellectual development. These uses may require new social settings in the classroom, which may lead change of roles of teachers and learners.

There are several major constructivist recommendations for teaching and instruction that would allow for incorporation of computer technology in order to improve education.

Constructivists postulate that instruction should take place in rich contexts that reflect the real world and are as closely related as possible to contexts in which this knowledge would subsequently be used, thereby maximizing motivation and transfer (Underwood *et al.*, 1990). These authors also believe that carefully planned and sequenced instruction tends to be decontextualized and promotes inert knowledge. This mode of learning would also restrict multiple perspectives that would be important for transfer of knowledge. Therefore, while content domains can be predetermined, carefully sequenced objectives within these domains should be avoided. Instead, these perspectives should be encouraged and promoted by providing for collaborative and cooperative learning (Hannafin, Dalton and Hooper, 1987; Underwood *et al.*, 1990).

Some constructivists, attempting to justify their viewpoint, compare it to an extreme standpoint. On the opposite end of this continuum would be those who are involved in instructional systems design (ISD). ISD has roots in behavioural technology, and incorporates carefully sequenced instruction with systematic relationships among pre-specified behavioural objectives, instructional strategies and evaluation (Rieber, 1992). There appears to be a superabundance of students who do not apply what they learn in school and who can answer with words but are not able to apply their knowledge. Students also appear to consider education irrelevant but have little or no option on the established learning norms. Constructivism is argued as a resolution for these problems and could be viewed as an important evolutionary step in understanding learning and teaching, rather than a paradigm shift.

It should be noted that there is no conclusive evidence that one sort of media is better than another in achieving a particular learning goal. Various students with different learning styles respond differently to each medium. For this reason, media should be classified into cognitive media types and the type of learning should be matched to the cognitive media type. For example, pictures could be used as graphical displays of relations among processes, examples or as flow diagrams. Such an approach will allow the teacher to provide material closely allied to the teaching goal.

The development of interactive and multimedia types of teaching materials, therefore, must take into account interactivity and multi-modality, and must match the media to the learning goal (Amory, 1997). The computer, however, is proving to be the most efficient 'stand alone' technology that, if used rightly, can make teaching and learning situations more meaningful and fruitful than ever before.

At certain times and situations, though, directed learning is inevitably efficient and reasonable. Open-ended milieu may not be the best way to guide students towards potent independent explorations. It would be appropriate to explore the limits of teachers' and students' willingness to accept empowering learning. Since innovations that are more generative and exploratory alter traditional authority and expertise roles, they become vulnerable to more risk and ambiguity than most other types of classroom change.

Various innovative practices have been advocated and adopted in learning and teaching by educators and policy makers with little success in improving sustenance of learner interest and participation (Amory, 1997). This is truer in empowering innovations and calls for sagacity in their implementation.

It is hypothesized that cultural expectations about schooling and school organizational structures account for much of the resistance to change (Saye, 1997). However, many technological advocates claim that with attention to supporting organizational structures, their innovation will overcome the cultural resistances that have doomed other empowering efforts.

One of the basic constructivist assumptions is that empowerment should be intrinsically motivating because it serves a human need to seek information and solve problems. Applying this assumption to technological innovation, many researchers view acceptance and integration of technology as an evolutionary process. If technology is presented judiciously, individuals grow more comfortable and proficient in it and hence become more innovative in applying it to self-directed learning (Collins, 1991; Hannafin, 1992; 1993; Saye, 1997).

3. Educational theory

Unlike the times of Plato, Dewey, Rousseau, Locke, other renowned philosophers and educators of yesteryear, it is not easy to state with certainty the purpose(s) of education. Over time, the discipline has become stratified due to an increase in the complexity of knowledge areas that has lead to specialization and distinctive disciplines. Since ideals of life are eternally at variance, educational aims that guide and correlate with such ideals often reflect such conflicts in the emergent theories of education.

Different assumptions about learners and the nature of knowledge have contributed to a polarization of attributes about education giving rise to the two major facets, namely, "traditional" (closed, teacher-centred, or deductive) and the "learner-centred" (progressive, inductive, discovery or inquiry learning) approaches. These have evolved over time and are presently customarily referred to as "instructivist" and "constructivist" modes respectively.

3.1. Instructivism

The teacher-centred approach is the most widely practised educational model today (Carey, 1993). This is attributable to a number of reasons, among them the fact that teachers are more familiar with this approach as they saw it modelled through most of their own schooling experience.

Also, much of teacher education today prepares students for this type of role. Regardless of the reasons, researches and attempts by various bodies, institutions or individuals to recommend a shift to other role definitions have had little impact.

The instructivist approach rests upon the assumption that learners are disinclined towards education, that teaching is largely a matter of direction, compulsion and restraint (Moore, 1974). Adherents of this model emphasize what is to be learned, holding that education involves the learner in acquiring important knowledge and skills. This knowledge is usually seen as consisting of a number of distinct areas of understanding (such as mathematics, history, science), all of which need to be taught and learned as distinct disciplines. Learning is described as a linear-cumulative process (Schwebel and Ralph, 1974).

Likewise, efficiency in learning is also emphasized. Content and instructional strategies are prescribed by what is directly and immediately demonstrable. Roles are clearly differentiated in terms of programme developer, implementer and evaluator (Schwebel *et al.*, 1974). The programme developer defines the goals, content and instructional strategies. The implementer plays a passive role as conveyor of the prescribed programme to the learner. The evaluator determines when teacher and child behaviours diverge from the programme expectations. Schwebel *et al.* (1974) further point out that behavioral objectives that define norms for achievement at any point in the programme are established.

Behaviour is categorized as acceptable or unacceptable and a system of rewards and constraints is prescribed as part of the instructional strategies used by the teacher. Education is thus likened to a transaction between a full and an empty vessel. The teacher is a repository of socially important knowledge, skills, attitudes and all the accepted norms, whereas the pupil is empty and needs to be "filled". The typical methods are those of instruction and demonstration by the teacher, with passive reception and imitation by the learner. In general, cooperation amongst the learners is not stressed.

3.2. Constructivism

The notion of the teacher as expert is, however, though at a slow pace, being replaced by the idea that the teacher should facilitate and guide learning. According to Carey (1993) this represents a shift away from behavioural theories and toward cognitive-developmental theories of learning. He further points out that students assume more control of their own learning and the school becomes a resource provider that students access to achieve their learning goals. This essentially requires a radical revision of among other things, the teacher's role. Carey (1993) describes this as cooperative learning activities in a technologically enriched learning environment.

The facilitated environment is one that provides a safe, rich and challenging place for the learner to set goals, assess progress and plan new learning. The context in which the typical teacher operates today, and the expectations of administrators for teachers are not congruent with this role.

This mismatch is, in part, due to the differences in the implicit and explicit paradigmic assumptions of teachers, administrators, and teacher educators. The mismatch is particularly obvious in the area of educational technology (Schwebel *et al.*, 1974; Carey, 1993).

Of recent times, the term constructivism is used more often than discovery learning or student-centred approach to learning. Based on the work of Jean Piaget and Lev Vygotsky, among others, it is having ramifications for the goals teachers set for learners, the instructional strategies employed in working towards these goals, and the methods of assessment used by school personnel to document genuine learning (Fosnot, 1996). Fosnot points out that constructivism, as a psychological construct, stems from the expansive field of cognitive science. This is attributed particularly to the later work of Jean Piaget, the sociological work of Lev Vygotsky, and the work of Jerome Bruner. Howard Gardner and Nelson Goodman have also studied the role of representation in learning.

Implicit to constructivism is the idea that human beings have no access to an objective reality since we construct our version of it, at the same time transforming it in our own unique ways. With increase in knowledge and its stratification, there has been a debate between those who place more emphasis on the individual cognitive structuring process and those who emphasize the socio-cultural effects on learning (Fosnot, 1996). Terms such as 'cognitive constructivism' and 'social constructivism' are now common in the literature. These in themselves are further stratified.

To avoid imminent complications that would result in begging the question, the momentous question to address should be the interplay between them and to examine the common thread that holds them together. The extent to which student-centredness relies on a constructivist philosophy is however open to question.

Basic tenets of constructivism

The constructivist view of learning perceives students as active learners who already hold ideas about natural phenomena, which they use to make sense of everyday experiences (Scott, Dyson and Gater, 1987). Learning, therefore, involves students in not only adopting new ideas, but also in modifying or abandoning pre-existing ones. Such a process is one in which learners actively make sense of the world by constructing meanings.

Various educators of constructivist persuasion posit that meaning made out of the world is idiosyncratic. The combination of learners experiences and their pre-existing knowledge results in different interpretations of concepts. They argue that whatever is learned is within the context in which it is learned and what is already known. Also, constructing links with prior knowledge is an active and continuous process involving the generation, checking and restructuring of ideas or hypotheses. Learning involves adding to and extending existing concepts, as well as radical reorganization that may involve conceptual change. Constructivists also believe that students frequently bring similar ideas about natural phenomena to the classroom as they have shared experiences (Scott *et al.*, 1987; Sprinthall and Sprinthall., 1990).

Since the process of knowledge construction is adaptive in nature and requires self-reorganization, cultural knowledge is a dynamic and negotiated interaction of individual interpretations, transformations, and constructions. Also, as a result of constant social interactions, and, since most learning depends on language, learners continually share multiple perspectives. Free ranging inquiry, discovery methods, exploratory activity as well as cooperation in learning is therefore encouraged. Therefore, the traditional subject divisions and a compartmentalized curriculum are incongruent with this style of learning.

Since most writers consider Jean Piaget, a Swiss by nationality, the 'father' of constructivism (Mwamwenda, 1989; Sprinthall *et al.*, 1990), a brief account of his work is given. Much as his theory is an epistemological one, it has some basic ideas relevant to the task of establishing a framework for the identification of features common to learner-centred programmes (Schwebel *et al.*, 1974).

Piaget's work created a new and significant theory regarding the process of cognitive growth stages. Two criteria, system of thinking employed and modal age, are used to define the stages (Sprinthall *et al.*, 1990). In the sensory-motor stage (from birth to 24 months) learning is tied to immediate experience. Object permanence is learned at this stage. When a child moves into the pre-operational stage (2-7 years), language development allows the child to free-associate and fantasize; creativity is characteristic of this age. From age 7-11, the concrete operations stage, literal mindedness reigns.

Finally, at the stage of formal operations (11-16 years), thought enlarges to include possibilities, hypotheses, ideas and the perspective of others. Although children usually operate at the stage appropriate to their age, they are sometimes capable of operating at the next stage up.

According to Piaget, when new information is presented that does not fit the learner's current understanding, a knowledge disturbance is created. Taking in such new information represents accommodation. The next phase involves making the new concept fit with previous knowledge, that is, assimilation. Equilibration involves a balancing of accommodation and assimilation, leading to intellectual development. Current research on brain development supports Piaget's notion of cognitive development stages, though educators should be cautious in how they interpret the findings (Sprinthall *et al.*, 1990).

One of the more prolific Piagetian concepts denotes activity as a central ingredient of intelligence at all stages. Active learning experiences tend to promote cognitive growth while passive and vicarious experiences tend to have minimum impact (Schwebel *et al.*, 1974). Piaget also emphasized the primary role of the socialization process in organization of knowledge and communication if it is to be effective. He described a continuum of development characterized simultaneously by less dependence on spatial and temporal contiguity and an increasing dissociation between general form and particular content. In other words, the intrinsic relationship between the real object and knowledge about it is diminished in favour of the development of abstract forms for organization of knowledge.

Younger children use practical schemes to coordinate external actions and learn through the use of manipulative operations and direct experience. Older children, on the other hand, use operational schemes to coordinate generalizations about experience. As language assumes a more central role in the learning process, the learner is able to use exchanged experiences as a vehicle for learning.

The role of the teacher in a Piagetian school is difficult and complex. The teacher is expected to diagnose each learner's emotional state, cognitive level, and interests by mentally carrying out a theoretical framework. The teacher also needs to cautiously exercise their authority, at the same time encouraging learners to develop their own standards of morality. This means teachers have to be highly conscientious and resourceful professionals who continue to be co-learners throughout the process (Schwebel *et al.*, 1974). Their function is to help the learners construct their own knowledge by guiding their experiences.

However much Piaget contributed to the constructivist model of education, it is not short of criticism. One of the criticisms of Piaget's theory is that the end point of cognitive development, formal operations may be too limited (Sprinthall *et al.*, 1990). A focus on logical reasoning may exclude thought in other areas such as wisdom and/or creativity. Some educationists hold the opinion that traditional Piagetian theory is really not concerned with individual learners of exceptionally high levels of cognitive talent. The reason for lack of attention to additional stages of development may be that Piaget first concentrated heavily on the thought process of children and then on early adolescence.

The major implication of Piaget's framework is that the curriculum should not take cognitive development for granted. On the contrary, the curriculum should provide specific educational experiences, based on the learners' developmental level, to foster growth. It would be erroneous to assume that all learners function at the formal level in all domains.

3.3. Bridging instructivist and constructivist educational practices

This is an attempt to show that contrary to the common belief held by many, constructivism and instructivism modes of education are not so diametrically opposed. Rather, a sober approach that allows for constructive borrowing from the latter to mend any differences should be embraced in the effort to improve the outcome of our educational commitments. It is worth noting that, if, taken in entirety as extreme opposing trends, there is a likelihood of ending up with principles that would be of little utility to the educational enterprise. While many people still equate ISD with behavioural learning, many of its approaches and methods have tried to blend behaviourism and cognitivism in order to achieve learner-centred instruction which is still goal oriented (Glaser, 1991; Rieber, 1992, 1996). Many are based on expansion of reception learning models, wherein meaningful learning is seen as a progression through a series of stages along a continuum from novice to expert (Ausbel, 1968; Mayer, 1984; Rieber, 1992) or a hierarchy from lower level learning to higher level learning (Rieber, 1992, 1996).

In both instructivism and constructivism, the facilitator or teacher is considered to know more about the knowledge domain than the learner, as opposed to just being good at collaborating, questioning and encouraging. Since learning takes place in particular knowledge domains, the facilitator needs to make decisions regarding adequacy of the learners' knowledge base. In this endeavour, ISD analyses could substantially help the facilitator to determine where the learner's knowledge is weak, what is lacking and what experiences are likely to be most helpful. The facilitator is then able to make decisions and determine the zone of proximal development, as well as knowing when the learner no longer needs a particular level of support.

Another strong characteristic of ISD is its evaluation emphasis. Both summative evaluation, that is, systematic comparison with other pre-existing instruction to determine effectiveness, and, formative evaluation, information gathered during design/development to improve instruction, can be constructively employed by constructivists (Mayer, 1984). The processes involved in formative evaluation may be particularly useful in constructivism instruction. As a subject matter expert and/or target-population expert help review instruction and make recommendations regarding the adequacy of the instructional methods, anticipating any problems that may arise. Such advise may be crucial in constructivist learning situations where students are expected to work effectively both independently and in small groups, while the teacher becomes less directing and more encouraging.

Micro-worlds are seen to offer a compromise between the strict deductive approach of learning suggested by ISD models and pure inductive learning. A micro-world is a small but complete subset of reality in which one can learn about a specific domain through personal discovery and exploration. Constructivists assert that learning connections are initially made possible in a micro-world and later enhanced through learner control. This is in contrast to research on learner control of direct instruction, which frequently suggests that learners are often poor judges of their own learning paths (Rieber, 1992; Dede, 1995). Although micro-worlds are a constructivist invention, they can provide goal-oriented environments in which learning is achieved through discovery and exploration. The compromise is reached largely through a guided discovery orientation to learning in which the nature of the learning activity and experience is naturally constrained by the parameters imposed by a particular micro world (Rieber, 1992; Dede, 1995).

A micro-world offers a point of entry that matches the user's cognitive state so as to allow fruitful interactions to take place. There are, however, certain design considerations for micro-worlds that have to be considered for it to succeed as a constructivist mode.

These include a meaningful context that supports intrinsically motivating and self-regulated learning, a pattern whereby the learner goes from the known to unknown, emphasis on the usefulness of errors, anticipation and nurturing of incidental learning. This should culminate in a balance between deductive and inductive learning beneficial to the learner (Rieber, 1992, 1996).

Accordingly, where there are apparent irreconcilable differences between instructivism and constructivism, there is a need to investigate if contradictory views do really exist. As an illustration, the constructivist notion that instruction should not be pre-planned may not be an absolute point of view. In certain learning situations, preplanning and specific outcomes may not be debated, for instance, training of pilots or medical students. In such circumstances, prescription of certain aspects of the learning process cannot be avoided. Likewise, if students are held to particular levels or standards of performance, there need to be at least some level of pre-planned instruction. While it may be true that students construct meaning, this does not make it illogical to expect that in many instructional situations there be a considerable amount of shared understanding in constructed meaning (Dick and Carey, 1990). In this regard, it may be of help to the educational system to borrow certain aspects of instructivism and incorporate them to constructivism.

3.4. Effective teaching and learning

The effort to achieve aims in any educational enterprise exacts a clear perception of the means of achieving the desired outcomes. Barker and Wisker (1997) itemize what this endeavour entails: holistic appreciation, active learning, communication, collaboration and teamwork, problem solving, critical thinking and lifelong teaching. Regardless of the subject matter, it is important that the learner has an appreciation of where the subject fits into a global context. This should also be in consonant with the learner's interests and aspirations.

Active knowledge is concerned with the integration of information, knowledge, skills and values leading to understanding and the ability to take appropriate action on the basis of integration. The learners are then able to use and apply the information and concepts learnt as they can synthesize, reinterpret and contextualize the knowledge (Barker *et al.*, 1997).

The learner needs to construct personal mental models that are detailed enough to cope with various situations. The learner needs also to understand that their knowledge is tentative and capable of evolving with changing experiences. This should enable the learner to act appropriately in apparently contradictory mental models or experiences in problem solving situations. A requirement of the acquisition of active knowledge by the learner is communication and dialogue (Barker *et al.*, 1997).

The teacher's communication here includes specifying goals and objectives, learning materials and situations, giving feedback and supportive remediation and allowing a period of reflection for the assimilation and synthesis of the experience. The teacher provides the context, the means of engaging the learner, responds to individual learner's progress and adapts the learning environment to suit the learner by providing means of connecting to other related experiences.

At the end, the learner should internalise the knowledge and not just learn the teacher's mental modal operations (Kolb, 1984; Barker *et al.*, 1997). Group activities and discussions provide exposure to different viewpoints in this respect.

Having observed that constructivism entails all of the practices that would result to effective teaching and learning, it is argued here that it is an effective educational approach. However, it should be noted that certain aspects of instructivism could be helpful in some situations within the constructivist mode to improve certain learner exit performances.

4. Educational technology

4.1. Advent of technology in education

The use of computers in schools and other learning institutions is not widely accepted. This may be due to the use of conflicting curriculum philosophies.

The mind-set that a teacher brings to the educational process influences how the teacher regards the use of technology. White and Purdom (1996) pointed out that successful integration of instructional technology in learning institutions occurs in the context of 'awareness of the role of the teacher and the existing curriculum'. Debates on the value of technology may often be the consequence of differing and conflicting conceptions of a curriculum.

Early attempts to apply instructional technology (IT) [1] to educational systems date back to the beginning of the 1900s when Sidney Pressey introduced the first teaching machine in United States of America. Later, in the 1950s and 1960s, Science Research Associates produced commercial learning 'kits' that permitted self-instruction in basic skills of reading, writing and arithmetic. Programmed instruction became the predominant format for IT in the 1970s and early 1980s. The use of mainframe and computer resources in this way was a natural and logical progression in the development of IT (Blignaut, 1996; White *et al.*, 1996).

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[1] Information technology is a range of techniques available for the collection, organization, manipulation and dissemination of information using different media. It therefore includes the wide range of applications of computers in schools, communications technologies, radio and telephone, and technologies such as the processing of images or sound (Blignaut, 1996).

With the arrival of microcomputers in schools around 1978, enthusiasts adopted the vision of the computer as a mechanism for presenting programmed instruction. Consequently, the microcomputer Computer Assisted Instruction (CAI) paradigm, with focus on tutorial, drill and practice functions reflected behaviourist views of learning (White *et al.*, 1996). Computer technology was accepted as a versatile platform for assessing student knowledge, delivering individualized instruction, providing immediate feedback and evaluating student performance (Blignaut, 1996). Technological advancements were quickly assimilated into the CAI paradigm.

Initially, there was sequential videotape and then, random access mass storage media such as videodisc and compact disc read-only-memory (CD-ROM). Such technologies allowed a wide array of video, animation, sounds and images to be incorporated into instructional sequences to make them richer, and, hopefully, more effective (Blignaut, 1996; White *et al.*, 1996).

These, however, in many ways than not, incorporated many aspects of the traditional instructivist approach of education and the computer was used like a surrogate teacher. Such a system appeared not to offer much to the educational problem.

4.2. Storage and retrieval of information in learning (rationale for use of IT in education)

To be effective, a tool for learning needs to be in harmony with the learning process, and the computer, as an information processor, is better suited for this (Kozma, 1987). To explore and appreciate the potential of the computer as a tool for learning, there is need to examine the learning process and its limitations. There are three aspects of the learning process that are primary considerations in designing Computer Based Education (CBE). These include the limited capacity of short term or working memory (STM), the structure of knowledge in long-term memory (LTM) and the learner's use of cognitive strategies.

STM is where information from the environment is combined with the information previously learned (retrieved from LTM) to form new knowledge. The capacity of STM is limited. Most people can keep only about seven 'pieces' of information in mind before they start to forget some of it. This capacity is effectively increased by 'chunking' the pieces, especially if done so in meaningful ways (Gagne, 1985; Kozma, 1987).

Information in STM needs to be continually refreshed or rehearsed, or it may no longer be immediately available. This rehearsal of information however competes for limited memory capacity with new information that comes along and with information retrieved for current use from LTM. As a result, information in STM is lost or distorted as new information is obtained and capacity is reached. If all the information needed at a particular time is not available in accurate form, or cannot be obtained from the environment or from LTM, learning will not take place, or, mis-learning occurs. Even if learning is successful up to this point, it may not be retained (Gagne, 1985; Kozma, 1987).

Not all information that passes through STM is stored in LTM. It is thought that the longer the information stays in STM, or the more it is operated on or transformed, the more likely it is that it will enter LTM. It is then stored permanently. Forgetting beyond this point is a problem of retrieval. If information is stored in either verbal or pictorial forms, its retrievability increases (Gagne, 1985; Kozma, 1987). This is one of the major reasons for advocacy for CBE as graphical presentation and other utilities, including sound are available.

Learning is determined by the cognitive strategies that learners use. These include, among other strategies, scanning, searching, questioning, chunking, hypothesis generation and decision-making. Efficient learners have more automatized cognitive strategies, less efficient ones use more of their limited STM to learn (Gagne, 1985; Kozma, 1987). Knowledge of this is helpful as we highlight the diverse ways in which CBE can amplify cognitive abilities.

For these reasons, the role played by technology in education, particularly computers, is paramount as computers can make learners perform cognitive tasks better.

4.3. Cognitive computer tools

These are programmes that use the control capabilities of the computer to amplify, extend or enhance human cognition (Underwood *et al.*, 1990; Greening, 1998). They are designed to aid users in task-relevant, cognitive components of a performance, such as revision in the writing of a composition or computation in the solution of, say, biology problems. While learning, the performance is open ended and controlled by the learner.

Instructional strategies such as specifying objectives, giving rules, providing examples, asking questions, and evaluating answers, correspond to cognitive strategies such as determining a goal, inferring a rule, identifying an instance, posing a hypothesis, and testing it. Experienced learners already have these strategies in their repertoire, although they may not use them regularly, appropriately or efficiently.

Rather than performing the strategies for learners, as is the case with tutorial software, cognitive tools for learning prompt and model the process to evoke necessary operations and compensate for capacity limitations (Underwood *et al.*, 1990; Greening, 1998).

In summary, reflecting on the requirements and limitations of learning situations discussed, the computer can aid learning by performing the following functions:

- Supplementing limited working memory by making large amounts of information immediately available for the learner's use.
- Making relevant previously learned information available simultaneously with the acquisition of new information.
- Enabling learners to quickly retrieve previously learned information that is needed to help them in learning specific new information.
- Prompting the learner to structure, integrate and interconnect new ideas with previous ones.
- Providing for self-testing and practice, thus increasing the retrievability of information.
- Enabling the learner to represent and comprehend ideas both verbally and pictorially.

- Providing for the easy movement, consolidation and restructuring of information needed by students as their knowledge base groups. (Harper, 1987; Kozma, 1987; Collis, 1989; Barker *et al.*, 1997).

Some of the common applications or techniques in CBE currently under use or investigation are summarized.

The Internet:

Networked computers are becoming accessible to large sectors of the community. However, large volumes of information produced make it difficult to relate to the data in meaningful ways (Greening, 1998). This is on the other hand advantageous since the learner is self-directed and is able to select relevant attributes of the otherwise 'voluminous confusion'. This improves their problem-solving skills.

Hypermedia[2] and the WWW:

Amory (1997) highlights the fact that the most rapid developments in software over the past few years have been the systems that display text, graphics, sound and video over remotely connected computers. He outlined the importance of the World Wide Web (WWW) to educationists:

- The Internet operates on globally accepted standards, is designed to use minimal amounts of computer memory and bandwidth, allows for movement all over the world using links and is extensible.

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[2] Hypermedia can be said to refer to the integration of different forms of representation into environments which can have non-linear structures.

- WWW browsers (the software used to access Internet sites) display text, pictures, animations and video, and contain spreadsheets, word processors, databases, conferencing and other software components as well.
- Browsers integrate many different protocols such as file transfer protocol (ftp) and gofer (old style systems of information retrieval) and hypertext transfer protocol (http).
- Creation of web documents in hypertext markup language (HTML) is relatively easy as HTML coding can be learnt in a short time.
- The system is interactive, for example, the user is able to report findings, answer questions and view interactive animation and video.
- Most browsers contain integrated electronic mail (e-mail) systems.
- Most of the web software is free to educational institutions.

A single and free software package, therefore, can offer the ideal environment for the deployment of CBE that supports rich and diverse media, as well as allowing interaction, communication and collaboration. The use of Internet software also provides the opportunity for students to explore different cultures, enables searching of data bases, indices and libraries, allows for group discussion, and can be used as a creative tool for writing, drawing and programming (Amory, 1997).

The emergence of hypermedia has resulted in software that is viewed by many educators as demanding a cognitively-oriented approach to learning. Meta-cognition (the learners processes of monitoring and making decisions about their own learning) is a critical element in a well-designed hypermedia because of the high level of learner control that is exercised (Thomas and Macredie, 1994; White *et al.*, 1996; Greening, 1998).

The challenge for constructivist educators is to mould the tool to fit the requirement, as well as adapting some of its popular usage of instructivist principles.

Multimedia:

Greening (1998) notes that multimedia based learning can be classified according to the degree and responsiveness between the learner and the environment as either prescriptive (highly structured, in which the learner responds to sets of predetermined possibilities, such as menu responses), democratic (where there is evident proactive learner control), and, cybernetic (characterized by mutual interaction, in which the system learns from the user in order to provide responses which meet the changing needs of the learner).

The prescriptive class is an objectivist approach while the democratic is constructivist in orientation. These computer tools help improve cognitive faculties of learners when used effectively.

4.4. Current trends and successful implementation of CBE

Currently, there is a popular requirement for use of computers in the process of teaching and learning. This effort is not evenly spread in global terms, and, as a result, assessment of its general impact is problematic and uncertain. It is however apparent that a measure of confusion about effective roles computers can play in education abound. Amory (1997) attributed the apparent failure of CBE to a number of reasons, including technical difficulties in building suitable networking and administrative structures to capacitate

CBE, placement of inappropriate user-interfaces and the inadequacy of artificial intelligence to provide mechanisms that could make computers more responsive to learner needs. He also pointed out that there is limited research into the use of CBE, and, failure to execute appropriate educational pedagogies that could support CBE. In order to improve educational standards, it would be beneficial to investigate and reform these trends (Welsh, 1993; Amory, 1997).

Successful implementation of computers in higher education circles

Attempts to integrate computers into higher-level education are evidenced by the growing number of computer learning centres on college campuses and the allocation of funds for implementation and use of computers in the institutions of learning. Amory (1997) proposed guidelines for successful implementation of CBE. Computer technology introduced into schools should be owned and used by all participants, enabling equal access to learners, teachers, parents and authorities. All computers within an institution should be connected via high speed networks and institutions connected to the Internet. At the same time, the machines should be dispersed among the classrooms and not dominated by any single users. Also, internationally accepted standards should be used in establishing the infrastructure and deployment of the technology. Likewise, technology need not replace the use of traditional teaching materials, but augment and support the teaching (Amory, 1997).

However, the introduction and the re-education of communities to the advantages of constructivist learning styles could proceed without the introduction of technology. Introduction of technology should be used as a mechanism to drive the change in teaching philosophy (Welsh, 1993; Amory, 1997).

The use of computer technology has reached a level in its development that requires a critical examination of prior predictions concerning the range of educational tasks it would be able to perform with marked efficacy.

Further research with special concern in areas that would improve teaching and learning in the context of constructivism, focusing on domains where the computer can be used most effectively and productively is called for. In this endeavour, shortcomings of the technology need be considered as the impetus for further research to improve CBE. Some of the functions within educational domain that computers cannot perform are mentioned.

- Microcomputers can supplement conventional education, but cannot substitute for it.
- Most computer applications are complicated, and teachers prepared to use them are in short supply.
- New products and systems are being created and marketed in such profusion and high speed but with little standardization, making systematic and long-term planning difficult.
- Good programmes are uncommon because creating them is difficult, time consuming and expensive.

- Educators are only beginning to understand how to use microcomputers in education, therefore, teachers unfamiliar with the technology are often apprehensive of its use in educational endeavours.
- It is difficult to use computers to teach subject matter that involves judgement, intuition, improvisation and creativity.
- Microcomputers might not solve educational problems - notably in areas of equity, school finance, and divergent public expectations (Harper, 1987; Barker *et al.*, 1997).

If educators become wary of unrealistic ambitions of computer technology and emphasize research on ways through which the technology can best be used in education, the systems could improve teaching and learning standards substantially.

5. 3D visualization skills

5.1. Visualization techniques as problem solving tools

Visualization is a tool, or method, used to interpret image data and for generating images from complex multi-dimensional data sets (Rieber, 1995). Visualization includes both internal (such as mental imagery) and external representations (such as real objects, printed pictures and graphs, video, film, animation). It extends to all cognitive and affective outcomes.

Our sense of vision represents the most diverse source of information of the world (Randel, Morris, Wetzel and Whitehill, 1992; Rieber, 1995). Education and society as a whole transmits colossal amounts of information in visual form. Visualization, as in simulations and animations, is most frequently used in instruction in the presentation of information. However, visualization techniques are also powerful problem-solving tools, though they are rarely promoted as such in learning and instruction (Randel *et al.*, 1992). This is unfortunate, as history is full of fascinating examples where visualization has been an important cognitive resource in human discovery and invention (Rieber, 1995).

In the presentation sense, visualization is not a new phenomenon. It has been used in maps, scientific drawings, and data plots for over a thousand years, for example, the map of China in 1137 A.D. and the map of Napoleon's invasion of Russia in 1812 (Hearnshaw and Unwin, 1994). Most of the concepts learned in these images carry over to computer visualization. Increased availability of multimedia tools permits the design of instructional systems that incorporate unlimited variations and forms of verbal and visual information for both presentation and feedback. Since the field, from a computer viewpoint, is only a few years old, it is in a somewhat unstable and rapidly changing state of flux (Hearnshaw *et al.*, 1994).

One of the major forces that have driven the interest in visualization is the existence of relatively inexpensive microcomputers with substantial colour graphics features, which has made the capability to create presentation graphics.

The recent availability of powerful but inexpensive UNIX based graphics workstations has supported and encouraged the more advanced visualization applications. Another force has been the huge amount of data being generated by modern science, both in supercomputer simulations and by experimental means. This enormous amount of information is virtually incomprehensible and needs intervention for better perception (Owen, 1993).

Acquisition of the skill has become highly relevant, owing to the fact that the world has become volatile and flexible. This is probably the impetus for educators to become innovative, emancipating themselves from the perpetual restriction of being victims of change to become manipulators and originators of the same.

For learners to survive and thrive in the rapidly changing world, education systems need to emphasize the role of visualization and imagination as tools for exploration and problem solving.

5.2. Visualization skills and cognition

An important aspect of computer visualization is that it tends to even out characteristic visualization differences among learners as some think more visually than others (Friedholf and Benzon, 1988; Wexelblat, 1993). The computer makes it possible for groups of individuals, even if they are separated by distance, to collaborate in visual exploration whether in the artistic, design or scientific spheres.

Some of the major visualization skills or techniques that are likely to enhance analysis, interpretation and comprehension are discussed briefly.

Pattern recognition

Pattern recognition is a many-to-one mapping from the set of all the variant instances of the different patterns that can be identified to the set of these patterns' names (Uhr, 1973). Real world patterns are usually embedded in a context that gives many important clues as to the pattern. All of the patterns with which human beings deal are tautological and become intricate to recognize when they are dropped out of their contexts (Reed, 1973; Uhr, 1973).

Orientation of form

Learners find identification of form rather more difficult with objects which are habitually perceived in one particular orientation, for instance, the upright position, when spatial presentation is altered. For example, Vernon (1970) reported that pictures of real objects, when turned through 90 degrees, with all surroundings obscured, could be identified in only 15% of cases, as compared with 66% when they were upright. Particularly, meaningless shapes are liable to appear different when orientation is varied.

Spatial framework and perception of distance

Differences in brightness between different parts of an object may contribute, as 'shadow', to the impression of three-dimensionality.

The receding sides of a solid object, and any part of its surface in relief, tend to be shadowed on the side away from the direction of illumination. By changing this direction it is possible to produce a change in the appearance of relief into that of protrusion. Objects equally illuminated from all sides may lose their 3D appearance and be perceived as flat.

Selective emphasis

This allows the detection of previously hidden patterns by highlighting certain features of the data and suppressing others.

Transformation

Non-visual data can be transformed into a visual image by mapping its values into visual characteristics.

Contextualization

Involves providing a visual context or framework within which the data may be displayed and interpreted (Wexelblat 1993).

In order to amplify learner cognitive faculties, certain considerations about visualization techniques need to be underscored. These include:

- Size invariance: learners trained to discriminate between a pair of shapes transfer the discrimination when the sizes of the shapes are altered.
- Equivalence of outline and filled-in shapes: learners transfer learned discrimination between filled-in and outline shapes.
- Non-equivalence of rotated shapes: not all rotations of a shape are treated as equivalent to the original shape.
- Perceptual learning: learners have the capacity to learn to identify specific objects and classes of objects that enable them to recognize new members of the class (Reed, 1973).

Learners do not often use such innate capabilities, perhaps because schools emphasize verbal skills and abstract reasoning over concrete reasoning.

The idea of using simple visualization as a cognitive strategy to help solve problems is frequently either overlooked or discouraged (Rieber, 1995). In order to motivate learners and enable them to gain self-confidence, instructional technology may be balanced to let the user become a co-designer of learning environments (Rieber, 1995). It should also be noted that initial learning experiences in visual thinking need to be short and well related to present knowledge (McKim, 1980). These factors need to be considered when incorporating visualization skills into a curriculum.

5.3. 2D and 3D visual skills

Given the fact that almost all manifestations in real life situations are in 3D, most learners are faced with the difficulty and complexity of recognizing discriminating features that are presented in 2D. Most learners configure and mentally rotate models presented in an attempt to discern and comprehend them.

This situation can be eased if 3D skills are introduced to the learners at early stages of education (Brodlie *et al.*, 1992). Through images displayed by computers, support is provided to learner information processing, enhancing mental visualization and the comprehension of 2D and 3D spatial relationship problems (Hearnshaw *et al.*, 1994).

3D displays activate more neurons thereby involving a larger portion of our brains in solving problems. Another important advantage of using 3D displays is the way they appeal to the brain and eyes.

A 2D plot of individual elevations does not appeal to viewers as much as 3D ones. The computer aided 3D display techniques simulate the manual techniques that have been developed and used by geologists for many years. Contours on a surface from point elevations, fence diagrams, multiple surfaces and perspective drawings, originally done by hand, can now be produced quickly and efficiently by a wide variety of computer programmes (Driel and Davis, 1989) thereby improving visual skills.

5.4. Visualization in Cartography and GIS

Cartography is the organization, communication and utilization of geo-information in graphic, digital or perceptible form. It includes all stages from data preparation to end use in the creation of maps and related spatial information products.

Maps are central to all geographic information systems (GISs) both as a source of input and as a means of demonstrating the output from such systems (Taylor, 1991). A GIS is a system for capturing, storing, checking, manipulating, analysing and displaying data that is spatially referenced (Hearnshaw *et al.*, 1994).

The concept of a map allows the relationships between a wide variety of both qualitative and quantitative data to be organized, analysed, presented, and communicated. Cartographic cognition is a process that involves use of the human brain to recognize patterns and relationships in their spatial context. The advent if GIS has improved cartographic cognition significantly (Taylor, 1991).

Visualization attempts to provide intuitive appreciation of the salient characteristics of a data set and to map relevant aspects of the data, which may or may not be visual in nature on to visual representations that can be understood easily and intuitively by the learners.

Maps are limited to 2D thereby giving a distorted impression of spatial distributions on the globe, are static (cannot change through time or animate), do not clearly represent interactions or flows between places, and show uncertainty in data (give a false impression of accuracy) (Taylor, 1991; Hearnshaw *et al.*, 1994). Computer generated displays are seen as promising to provide solutions to these complications as they include raster and vector graphics, can be animated, can show continuous gradations of colour, texture, tone, and can show 3D using stereoscopic technology.

Visualization research suggests that if images similar to the natural 3D world are used as a model, both analysis and communication may be improved (Driel *et al.*, 1989; Taylor, 1991).

Of recent times, attempts have been made to provide visualization education for students in certain academic fields. For example, 3D modelling and visualization have been incorporated into a first year 'engineering concepts course' at the University of Virginia. The basic ideas of visualization are introduced to students during their first semester. Students are reported to find this exciting, challenging and relevant (Owen, 1993). They learn to capture their ideas as 3D models and gain an early understanding of the role of design in engineering.

Also, a visualization course at the University of Illinois is taught at graduate level, taken mainly by computer science students, with a prerequisite of a computer graphics course (Owen, 1993). At College Station, Texas, currently, an educational programme that specializes in visualization is located at the Visualization laboratory (Owen, 1993). From these illustrations, it is observable that there is need for deliberate research oriented towards use of the techniques in situations other than in computer science units. Emphasis should be made on the use of the techniques under the principles of the constructivist educational approach, and for students with non-computing backgrounds.

6. CBE and curriculum design

6.1. Paradigms in curriculum

Teachers, administrators, teacher educators, policy makers, researchers and parents aim at making decisions that facilitate the holistic growth of learners. To achieve this, educators need to be committed to a process of discovering what knowledge is valuable, why it is valuable and how it can be acquired. Lack of clearly articulated principles of curriculum process and development has led to most of the problems facing education (Schubert, 1986; Grundy, 1987).

The term paradigm as used in this discourse refers to a set of principles, values and beliefs that determine educational decision-making and action. On the other hand, the term curriculum is conceptualised in different ways.

The 'hidden' curriculum, for instance, may refer to the aspects of learning overtly included in planning within an educational system. The official (formal) curriculum concerns what is laid down in syllabi. The actual (received) curriculum on which this discussion is based refers to what is covered in the practice of the learning institutions. The difference between these may either be conscious or unconscious (Schubert, 1986).

Various ideas about learning shape the curriculum. For example, educators of the social behaviourist persuasion concentrate on management, emphasizing control and giving efficiency precedence over worth. Intellectual traditionalists on the other hand assume that subject matter is intrinsically worthwhile when it enters the growing repertoire of each student's experience. If a learner is not capable of interpreting a body of subject matter or deriving meaning from a literary classic, for instance, the effects of this theory may be detrimental to the learning process (Popkewitz, 1984; Schubert, 1986). Likewise, since real world problems are not arranged to fit subject boundaries, it is not particularly useful to present educational or curricular enterprise into rigid job specializations. Similarly, curriculum teaching that leans heavily on the idea of mental discipline tend to be narrow in objectives and unitary in scope, and the sequence of content or the continuity of learning experiences is not considered being particularly significant (House, 1979; Popkewitz, 1984; Schubert, 1986; Grundy, 1987).

Different curriculum paradigms can enable us to gain insights into the relationships of elements at interplay within an educational system as they help us uncover principles underpinning convictions and practices of individuals involved. The three major paradigms are technical (empirical/analytic) which assumes knowledge to be value free or law-like; critical (emancipatory) which assumes the necessity of ideological critique and action, and seeks to explore that which is oppressive and dominating; and the practical (hermeneutic) paradigm which is concerned with interaction, collaboration and participation, and, that knowledge is socially constructed (Popkewitz, 1984; Grundy, 1987).

Although there are overlaps within the three sets of curriculum paradigms, since it is not possible to absolutely distinguish between the different values, beliefs and principles that underlie each one of them, the practical paradigm is identifiable with constructivism and CBE. Basically, the practical paradigm's mode of rationality includes emphasis on understanding and communicative interaction. Human beings are seen as active creators of knowledge. The practical paradigm looks for assumptions and meanings beneath the texture of everyday life, views reality as inter-subjectively constructed and shared within a historical, political and social context, and focuses on meaning through language use (Popkewitz, 1984; Grundy, 1987).

Curriculum development enterprises need to consider the socio-political milieu in which those affected by it fall.

For that matter, any discussion of knowledge, skills and curriculum change in higher education should be based on the relationships of politics, control, power and culture that influence the educational process (Beijnath and Hendricks, 1993). In South Africa, new socio-economic dynamics have radically transformed the outlook for the future, growth imperatives, educational needs and the prospects for significant change in the distribution of power and resources. There is therefore need for re-examination and reform to an insightful paradigm, characterized by among other pragmatic principles, flexibility and relevance of the learning process to learners.

Curricular content should be correlated with, or designed appropriately, to the stage of development, cognitive or moral, at which students function (Schwebel *et al.*, 1974; Schubert, 1986). Teachers should try to get students to master what they learn and not use one method or approach exclusively in the process. Schubert (1986) commented:

"it is ... common sense to look for learning styles of students, but ... there are many, many more styles than presented in the flaccid categories of those who make a mint from selling diagnostic instruments and instructional materials that pigeon-hole students more than they liberate them. Inquiry teaching is worthwhile, but only if it is spontaneous interaction between teacher and student, as it was with Socrates and his charges. There is nothing so incongruous as a kit of pre-specified questions that are billed as Socratic" (P. 257).

This statement by Schubert succinctly summarizes the attitude that needs to be adopted in curriculum deliberations. Also, curriculum should be developed by those who will be affected by it (Beijnath *et al.*, 1993). This makes curriculum primarily a matter of democratic interaction between communication, individuals and society needs. If a curriculum is to be considered relevant for and by the learner and if the educational programme is intended to extend to other aspects of the learner's life outside the classroom, use of the larger environment of the learner becomes an important consideration for programme developers and implementers (Schwebel *et al.*, 1974; Schubert, 1986).

6.2. Perceptions of curriculum

Since paradigms are seen as precepts, thoughts and beliefs that form a distinct view of reality, the various paradigms shape the nature of the curriculum in educational systems thereby determining practices relating to use of IT as a learning resource. Different mindsets generate different proposals in educational practices. White *et al.* (1996) describe a system of categorization of the mindsets that includes curriculum as technology, academic rationalism, development of cognitive processes, self-actualisation and social relevance-reconstruction.

Modern IT and academic rationalism

Educators who adhere to the academic rationalism conception, labelled as classical or traditional, believe that subject matter from the established academic disciplines is the critical substance for intellectual growth. They focus on teaching of 'classical' subjects. Educators of this mindset tend to be hesitant to endorse CBE because they think the goal of such software is to replace teachers (White *et al.*, 1996).

Modern IT and self-actualisation

This is the belief that the most important outcome of schooling is maximum development of each individual's potential. Education should therefore develop the special abilities, skills and interests of each individual to the maximum. This mindset is often referred to as the humanistic, 'whole child', or personalized conception of the curriculum.

Educators of this conception view technology as removing the human aspect from quality education and thus may have negative repercussions (White *et al.*, 1996).

Modern IT and social relevance

Adherents of this philosophy believe that the needs of society are the highest goals, education is the means to realize them and so the curriculum must be directed to that end. However, there are two opposing views within this. One view (adaptive) sees the curriculum as an instrument to help students adapt and fit into society, the other view (reformist) sees the curriculum as an instrument to help students change the world to a better society. Each of the different view has different implications for IT. The 'adaptive' view believes that schools must instil computing skills in learners who will be the work force of the next generation. On the other hand, those who subscribe to the 'reformist' persuasion are suspicious of how technology is being used by those in power. Since the reformists want to explore society, discover inequalities and eliminate injustices, the use of computers and related technologies is antithetical to their mindset. Although they have grave reservations about the use of technology, some social reconstructionists believe that acquiring literacy skills enables learners to study certain issues of importance (White *et al.*, 1996).

Modern IT and development of cognitive processes

Although intellectual development is also a prime consideration of the academic rationalism conception, some educators think there are generalized, domain free, cognitive processes that can be developed regardless of the subject matter.

They value intellectual process over content and believe that any content can be used to facilitate problem-solving, critical thinking and higher order thinking processes. Cognitive processes oriented educators tend to embrace IT. According to them, problem solving and simulation software can cause learners to think creatively across multiple disciplines, and can often be used in cooperative groups (White *et al.*, 1996).

Following the discussion above, it is observed that effective policies for the whole curriculum should embrace the aims, purposes or principles of the institution, selection and arrangement of studies and activities, methods by which these studies and activities are to be mediated, availability of the curriculum to learners and the principles governing its availability. Also, methods of curriculum planning and strategies for curriculum development, methods of assessment and evaluation, local factors and the claims of the community need to be considered (Davies, 1976). The curriculum is always subject to debate because of its intimacy with social and political values. Much of what influences the intended curriculum is 'hidden' and may not be made explicit if it is not to defeat the intended curriculum. The task for educators is to find in which contexts, at what stage, and with which learners different approaches are most productive. There are dangers that too strong an emphasis upon any one mode of teaching may produce strain upon learners who often benefit from an appropriate blend of approaches (Davies, 1976).

7. Conclusion

Approaches that could impart skills and competencies that learners are able to relate to real life situations and employ in day-day problem solving situations have been advocated. Such expectations are not easy to realize. Many attempts by educators and researchers have been futile. Constructivism, in conjunction with CBE principles has been argued to be a philosophy that promises to provide solutions to this quagmire. It has also been argued here that visualization capabilities elemental in learners' discrimination, retention and retrieval of information, need to be reinforced to improve performance.

Also, an understanding of curriculum implications is imperative in the undertaking of reconciling education and technological advancement.

CHAPTER TWO

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1. Introduction

It has been argued that 2D and 3D visualization skills are required to understand many basic biological concepts. To design appropriate curricula that could allow for the development of such skills, it was necessary to determine which skills academics thought were required; to evaluate student 2D and 3D perceptions skills; and to investigate the use of computer tools in developing such skills.

In this chapter, each part of the investigation will be reported separately and includes a brief introduction to the research problem (identification of specific visual problems in learners) (p. 1, Chapter 1), methods used to investigate the problem, results obtained and a brief discussion of the results.

2. Convictions and experiences of university lecturers on visualization techniques

2.1 Introduction

The first part of the investigation used face-to-face interviews with members of the School of Life and Environmental Sciences, University of Natal, Durban, to determine attitudes and opinions of experts for the requirement of 2D and 3D visualization skills in biology students.

A qualitative research approach was used to gain insights into deeply embedded convictions and opinions that underpin university lecturers' reflective persuasions. This method was preferred because of its unique qualities of flexibility, ability to probe in order to clear misunderstandings, to create rapport, to elicit unanticipated or unexpected responses that would suggest novel hypotheses, and the added advantage of being able to observe non-verbal communication in forms of auditory and visual cues (Patton, 1980). This author argues that qualitative inquiry provides both depth and detail. Cohen and Manion (1985) recommend interviews as a form of social interaction that may provide access to an individual's (or a group of individuals') knowledge or information, values and preferences, attitudes and beliefs, or any other experiential and subjective orientations or mental content. The view is sustained by other notable qualitative research method propagates (Banaka, 1971; Cohen *et al.*, 1985; Krueger, 1988; Creswell, 1998).

2.2. Materials and Methods

2.2.1. Interview sessions

All academic members (experts) of the School of Life and Environmental Sciences (n=13) accepted to be interviewed after receiving an electronic message requesting their participation in the process. The electronic message included a covering letter indicating the scope of the face-to-face interview (Appendix 1) and some brief explanations of terms to clarify any unfamiliar concepts.

The interviews took place in the offices of the participants. Time schedule for the interviews fell between 09.00 h and 16.00 h spread over a period of three weeks. Interview duration ranged between 20 minutes and 70 minutes. This enabled a candid and in-depth interview culminating in a clear perspective of the convictions, experiences and opinions of the lecturers regarding the use of visualization skills in teaching and learning.

While telephone calls during the interview session caused interruptions, many staff members disconnected their phone lines. Due to unforeseen events, a few interviews had to be rescheduled.

Each interview was audio-recorded and then transcribed into QSR NUD*IST 4.0 (Qualitative Solutions and Research - Non-Numerical Unstructured Data Indexing Searching and Theorizing). Authentic names of the participants are used in this text as none objected[3].

2.2.2. Content of interview

The electronic mail requesting interview sessions contained three sections. The first section was a covering letter asking the staff to suggest day, time and place convenient to them where the interview could take place. The second part included brief explanations to some visualization skills that learners may require. The goal of visualization skills was briefly explained in context of research objectives and general CBE principles. The third section contained ten loosely structured questions (Appendix 1).

The first question sought to find out whether visualization skills are necessary to aid instruction in topics taught by the lecturers. This was asked in order to establish the relevance, or need for (image) data interpretation techniques, that would be enhanced

[3] The members of the focus group included Dr. Adams, J., Dr. Lamb J., Mr. Page, B. R., Dr. Campbell, G., Dr. Contrafatto, C.G., Dr. Watt, M. P., Prof. Appleton, C., Prof. Pammenter, N. W., Mrs. Singaram, V., Mr. Kioko, J., Prof. Berjak, P., Dr. Slotow, R., Prof. Forbes, A. T.

and developed by computer-based resources. This premise was to elicit responses that would either qualify, or disqualify, the relevance of the skills in a learning context.

The second question required the lecturers to state if their courses needed visualization skills, and, if so, specific skills they thought the students required. Respondents were expected to illustrate the skills or techniques that they thought learners needed, or that they used in instructional exercises. If unsure of categories where particular skills would fall, they chose skills applicable to their cases from broad categories given in the introduction prose.

To establish whether introduction of visual skills would be a gainful undertaking, respondents were asked whether the students had a grasp of visualization skills, that is, whether or not they were able to interpret image data with which they were presented.

The respondents were then asked whether they had observed changing/improved levels of visualization skills with age or advance in levels of learning. This was to determine if learners would be able to benefit cognitively from the skills, and, the effect of age with reference to visual skills.

To find out the effects of exposure to 3D environments and role of interaction with the environment, respondents were asked to recount their experiences with learners of different economic backgrounds with regard to visualization skills.

Respondents were then asked whether or not visualization skills were transferable. This was to establish whether general visualization skills would be transferable as to aid instruction in topics taught by the lecturers.

To be able to make a proposal for incorporation of 3D visualization skills into the course on a needs-based criterion, participants were asked if all, or only some, of the students needed to acquire perceptual skills.

To be able to establish an effective way to introduce visualization skills in to the course, respondents were asked to state whether it could be a part of a biology course, or whether it would be introduced as a separate course.

To determine the most effective stage within the Biology course when the skills would be most beneficial to learners, the respondents were asked to state the stage they thought the concepts could be introduced within the Biology course.

To ensure that skills to be introduced would be relevant to learners, respondents were asked to explain what skills they thought could be included in the course to improve learners' cognitive ability.

2.2.3. Qualitative data analysis

QSR NUD*IST 4.0, a software for qualitative data analysis, was used for data management and analysis. Creswell (1998) attests that researchers generally overlook specific applications of computer programmes in analysis of traditions of inquiry, even though they aid in analysis and representation of data.

He quips that NUD*IST, a theory generating programme, is suited for qualitative analysis because of the in-built capabilities of storing and organizing files, searching for and crossing themes, diagramming, and creating templates.

2.3. Results and Discussion

2.3.1. Detailed account of interview results

Middlehurst and Barnett (1994) underscore the importance of close consultations with subject experts in any innovation that ultimately affects them. In light of this, lecturers within the School of Life and Environmental Sciences were well placed to point out perceptual learner problems and suggest viable remedial actions. Generally, the participants responded enthusiastically and with concerned attention. Most found the enterprise interesting as it entailed matters with which they were engrossed at the present. More so, interview date, time and place was set conveniently by them.

When asked whether visualization skills were necessary to aid instruction, all the participants (13/13) agreed that the skills were necessary (100%). One observed:

"I would say that if one is to benefit to the maximum from the courses they (students) do require these skills on the part of the business to it".

All of the participants said that their courses required visualization skills. Skills recurrently mentioned included projecting 2D material into 3D objects and vice versa, orientation of form, rotation, learners ability to draw and describe accurately what they see, having mental series of succession of different phases of various operations, ability to visualize size and scale differences, puzzles.

"It's mostly being able to perceive things in 3D, being able to perceive shapes of objects, the physical spatial relationship between one part of an object and another".

This conforms to Gardner's theory of spatial intelligence which concerns the ability to perceive visual or spatial information, to transform and modify this information, and to recreate visual images even without reference to an original physical stimulus (Gardner, Kornhaber and Wake, 1996). This visual skill is also an important part in the cognitive development of learners (Rieber, 1995).

On whether students have a grasp of visualization skills, in various topics taught, most respondents conceded that even though they did not formally test it, some learners were able to interpret image data better than others. This discrepancy was attributable to faulty visualization techniques inherent in learners drawn from the diverse backgrounds, and of different levels of intellectual experience. One respondent said:

"Some of them do, some of them don't. At the first year level, some people would find it quite simple to translate an image of a 3D object into a 2D drawing, others struggle tremendously".

In concurrence, another respondent said:

“They certainly get no formal instruction in visualization, so I suspect they probably won't have a grasp of visualization, probably not always, it certainly would help them to be able to visualize things in 3D".

The respondents felt that as a result of direct experience, learners are able to exhibit improved levels of visualization skills.

“One would think that they would get better with age, that would be my intuitive impression and the more times they have to use these visualization skills the better they are going to end up being at doing it. I think a lot of visualization skills come from life experience, and I don't think you necessarily can train people in it that easily”.

The above view decreed a closer scrutiny as it would eventually enable the researcher to determine more appropriately the stage to introduce visualization skills to learners. It would also guide the researcher in authoring/designing a computer based educational device aimed at helping to correct identified weaknesses (see Section 3 of Chapter 4).

Answering the question whether there were variations in levels of grasp of visualization techniques in learners of different economic backgrounds, the respondents felt that, even though they had not formally examined it, learners who came from high socio-economic backgrounds might exhibit superior visualization skills to learners from poor backgrounds who lacked most gaming and educational facilities. Interaction with 3D visualization environments would be limited for learners from the economically challenged category. Implicitly, responses about visualization skills and influence of environmental factors were indicant of the fact that learners from urban areas were better off than the ones from rural areas.

"I think students from rural areas are very limited in what they've been exposed to, in terms of modern technology".

All of the respondents said that visualization skills were transferable and would aid instruction. An informant remarked:

"I do think it's transferable, and certainly it would be of assistance, particularly the topics I teach in regard of enzyme function and also interpretation of important characteristics or identification of important 3D characteristics of animals as they relate to how they are classified. There are many areas in biology, not restricted to the subjects that I've been talking about or the disciplines that I teach where it'd be useful for students to be able to develop this mental image of 3D structures from 2D images".

This disclosure was a principal consideration in the proposal of incorporation of 3D visualization skills into the curriculum. Four of the respondents however had some reservations on the transferability of visual skills. They observed that although this would be possible, it may neither be easy nor can the transfer occur absolutely.

"I don't know if teaching of these visualization skills are transferable in the short term. They are a result of cumulative life experiences, in other words you need to have a pre-existing set of knowledge in order to be able to easily learn certain kinds of new things, and if you don't have that pre-existing set of special knowledge then you're not gonna be able to teach people like that new spatial concepts, I think it might help but whether it might be a great help in the short term with a course like biochemistry is not clear to me".

On the same pessimistic note, another respondent referred to Rubik (who invented the rubik cube), recalling that he might not have been impressed with the results when he attempted to use the invention to transfer visualization skills to his students.

The respondent felt that for this reason, it could probably be something that is developed subconsciously, may be over years. He underscored the impact of age and intellectual experiences that came with it. These claims were further examined in the following stage of survey where students were interviewed.

Eleven of the thirteen participants responded that all learners should learn some visualization skills (85%).

"I think all students should learn some visualization concepts, even students who come from the schools with better resources may be developed in some of these areas but not in others, so I think in many cases all of them would be developing some new visualization skills and for those who have some experience they'd just be reinforcing or improving the visualization skills that they've had some experience with already".

One felt that the skills should only be introduced as a remedial measure, if such cases were identified.

"I don't think they should all learn general visualization concepts. I think they all do in the course of life experiences and what they are exposed to, I don't think there should be a sub-course on visualization concepts in a biology department. I think it should be dealt with in specific contexts".

Eleven of the thirteen participants said that visualization skills should be made part of the Biology course rather than introduced separately (85%).

"I think visualization techniques are an embedded part of certain biological practical skills and one cannot take them out, but, if there's some fairly short means of achieving the same and more effectively, perhaps before one begins with biology, it may well be advantageous".

One respondent felt that both ways would give favourable results.

"Both ways they should be able to benefit, being in the biology course I think that they would learn things that are pertinent, within the subject of biology, if visualization techniques was a course on its own then may be it gives that course a chance of exploring more, than what can be covered in the biology course".

Twelve of the thirteen participants said the most effective stage of the Biology course to introduce visualization concepts would be at the beginning (92%).

“As soon as possible. I do believe it's an age-related thing, it's something that develops from the age of eighteen to twenty five so we are getting them really at the lower end. I'd say the sooner the better”.

When prompted to suggest exercises that they think could be included in the course to improve visualization skills in learners, the participants mentioned a range that included 3D computer games, manipulating objects in different orientations, projecting 2D material in to 3D objects and vice versa, identifying 3D objects oriented differently (rotation), puzzles, ability to interpret microscope slides of sections, cutting sections (sectioning exercises), looking at something in detail and being able to draw angles and proportions, model construction. One respondent said:

“Drawing 3D objects, drawing exercises, possibly even simple things like having 2D drawings of objects having, the physical objects themselves and matching those, and you can make these objects quite complex, they don't have to be just simple squares and cubes”.

The responses to the questions in the last part of the interview, together with quantitative analyses of the 3D tests given to the first and second year Cell Biology students (results from the second stage of the project) formed the basis on which the educational game (Section 3 of Chapter 4) was designed.

2.3.2. Summary of interview with staff of the School of Life and Environmental Sciences

To examine the extent to which 3D visualization skills can improve learner perception of various concepts, the interviews revolved around the most effective stage to introduce a specific skill in an undergraduate course; influence of prior experience or exposure to 3D visualization environments; and viability of introducing the skills/techniques to a course as a measure to enhance and improve student performance and learning skills.

Twelve out of thirteen respondents strongly felt that it would be helpful to introduce visualization skills at the beginning of the undergraduate course (93%).

Since remedial courses may be necessary in later stages if they are identified, some respondents suggested that the skills do not have to be necessarily limited at the first year level.

On exposure to 3D visualization environments, 93% of the respondents agreed that prior experiences do have an impact on the learners' visual skills.

Even though some commented that the vast majority of their students were drawn from urban areas, it was unanimous that exposure, and, the extent to which learners interact with their environment impact a great deal on the development of the visual skills.

Considering the past history of South Africa's apartheid regime and the racial restrictions, some respondents argued that the former regime was responsible for the evident inequity. For that matter, economic status as well as exposure was tied to racial lines in such a way that the White colonialists had superior infrastructure to the disadvantaged Black, Indian and Coloured counterparts[1].

Rather than taught separately, twelve of the thirteen respondents suggested that introduction of visualization skills to a course should take an integrated approach (93%).

2.4. Conclusion

Qualitative data provide both depth and detail which gives researchers insights to deeply bound opinions and convictions of individuals (Patton, 1980; Cohen *et al.*, 1985; Krueger, 1988; Tesch, 1990). Since lecturers have first hand knowledge of the learners' need areas and deficiencies, the interviews were unequalled rich source of information. The general feeling (77%) was that visualization skills are necessary and should be introduced as an integrated course at the early stages of the undergraduate curriculum. This was ultimately arrived at when the respondents were prompted to give a general comment at the end of the interview.

"I think it's a wonderful idea, and I think that the sooner we can get into the work the better because I do believe that biology students need to be able to visualize in 3D, and I do think there's an enormous deficiency there".

[1] Reference to this was generally implicit and was not audio-recorded for transcription when the respondents felt uneasy speaking about it.

Three respondents felt that the skills are important but were skeptical whether they can be easily taught and transferred. However, they concurred that there is inherent ability in the learners and exposure to visualization skills would certainly be of help.

These views provided insight to the design of the educational game as well as propositions to its inclusion in to the curriculum.

3. 3D visualization skills assessment

3.1. Introduction

A questionnaire was designed in this part of the project to identify and quantify student 2D and 3D visualization skills. Quantitative exposé enhances an examination of the distribution, frequency, prevalence, incidence and size of phenomena (Tesch, 1990; Patton, 1990; Dey, 1993). Mostly, it involves systematically selected samples and may cover a large number of cases. It was therefore considered an effectual tool to identify areas of weaknesses in learners with regard to their use of visualization skills, complimentary to the qualitative methodology. This was done as a move to rectify the problems of depth and width that often arise from over-fascination with the one at the expense of the other method.

3.2. Materials and Methods

3.2.1. Sampling strategy

The sample was drawn from the University of Natal student population. Students from the Department of Biology were used, even though, at a less formal level, opinions of learners from other departments within Science, Humanities and Social Sciences were sought or observed.

A purposive sampling method was used. Of importance were prior experiments and findings by the Biological Pedagogy (Bioped) Research Group that Biology students exhibit conceptual difficulties in various topics. This was to establish observed problem areas with the aim of proposing corrective measures.

All members of the first and second year undergraduate Cell Biology classes were involved. The foreseeable limitation of this approach was that individual bias could prevail from the sample selected. This was checked by identifying the main contributing variables and characteristics in an attempt to ascertain that the sample would provide the information required. One of the considerations was that pedagogic styles in the undergraduate course entailed relatively high graphic resources. To this end, CBE is argued to provide a corrective strategy. Such a remedial measure was implied by Black (1993).

3.2.2. Experimental design

The sampling units arrived at were as a result of the need to examine particular causal linkages between learners' perceptual behaviour and academic year. It was felt that in order to establish the stage at which the identified visualization skills (Section 5 of Chapter 1) would be most beneficial to learners, it would be appropriate to observe learners at the formative stages of the undergraduate course.

The learners were observed and investigated in two time periods, namely, before getting involved in the educational game and after (pre and post-tests).

3.2.3. Nature and content of the 3D Test

A multiple-choice questionnaire adapted from standardized tests from the Human Sciences and Research Council (Appendix 2) was used. This was divided into three sections. The tasks in Part A required students to correctly match figures to identical rearranged ones. In Part B, students were expected to identify blocks of cubes with similar ones presented or viewed, from different angles. Part C exercises involved mentally folding/bending flat objects along indicated/dotted lines to come up with correct 3D objects. The students were also asked to indicate their gender and race in the questionnaires.

3.2.4. Administration of 3D Test

The test was administered to first year Cell Biology students (n=145) and second year Cell Biology students (n=45) of University of Natal, Durban. A zero score indicated an incorrect response and a score of one a correct one. The total sum of scores was regarded as a percentage. These were sorted in ascending order and ranked. The results were consequently compared, in relation to level of learning/academic year of students, gender and race using cross-tabulations and the Mann-Whitney U - Wilcoxon Test (SPSS - Statistical Package for the Social Sciences, SPSS Inc.).

These statistical procedures were best placed for the management and consequent analysis of such a non-continuous data set.

3.2.5. Sections of 3D Skills Test

In order to determine how students perceive objects presented in different perspectives and orientations, a Three Dimensionality Test (Appendix 2) was presented to the first and second year Biology students. Section A of the test required students to find and match figures to rearranged identical ones. Fig. 1 below shows the results of gender comparisons.

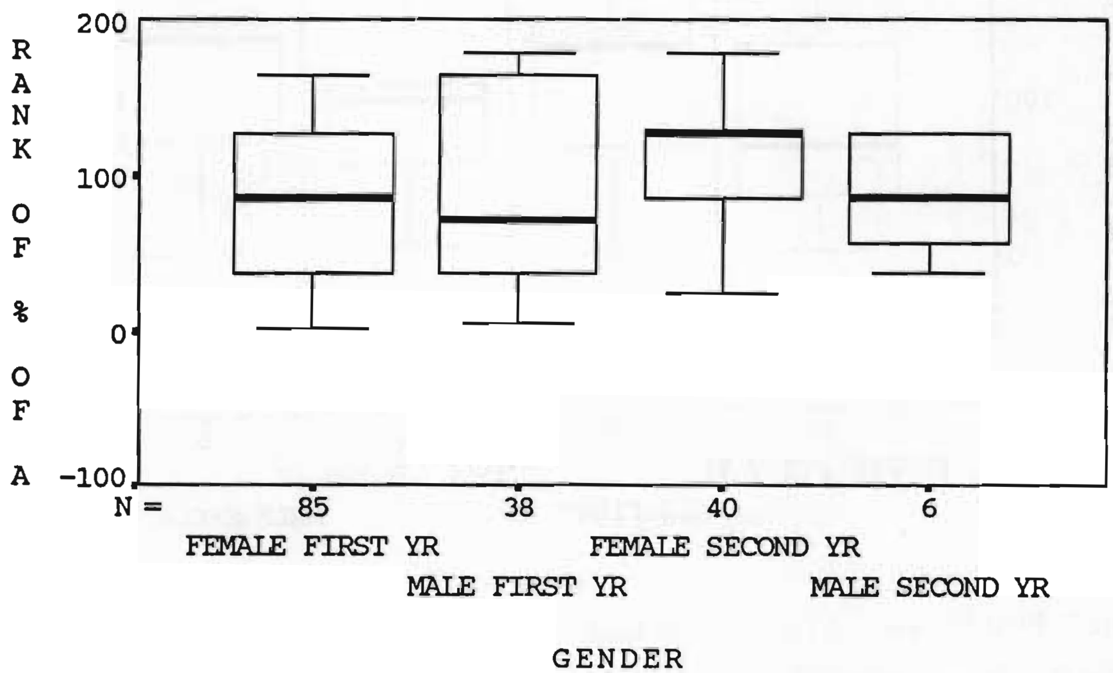

Figure 1. First year and second year biology student performance in Part A (identifying rearranged objects), showing gender categories.

Female students performed better than male students in tasks that required identification of rearranged objects (Fig. 1). Female second year students had a higher mean rank of percentages compared to first year students, even though they were skewed below the 100% mark. The mean was however still higher than that of the other categories. Second year male students had a slightly higher mean compared to first year male students even though their percentage ranks appeared more skewed above the mean than that of the first year students (Fig. 1). These results suggest females are better at pattern matching than males. It appears that more males are able to complete this task successfully than are females.

Section B required students to identify 3D cubes oriented in different angles (Fig. 2).

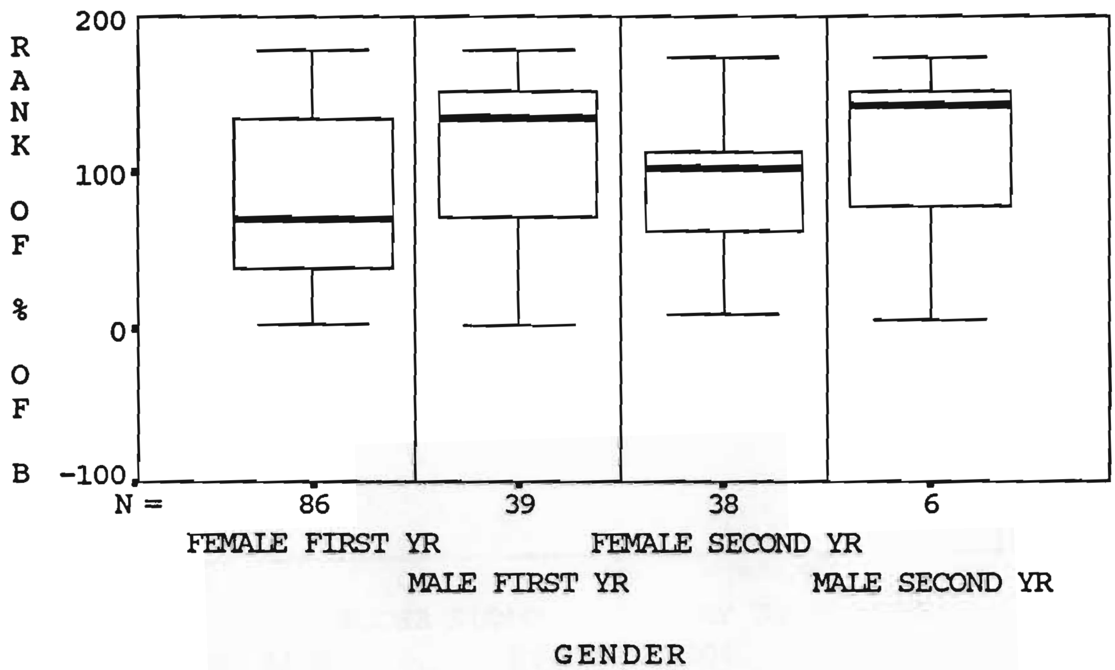

Figure 2. First and second year biology student performance in Part B (identifying 3D objects oriented differently), showing gender categories.

From Fig. 2, it can be seen that female first year students had the lowest mean rank, even though most of them were concentrated around the 100% mark. Second year female students had a higher mean than first year female students. This was however lower than that of first and second year male students. Second year male students appeared to have slightly better averages than first year male students. Therefore, male students appear to be better able to mentally rotate 3D objects in space.

In Section C, students were asked to mentally configure 2D objects, folding along perforated lines to form three-dimensional objects. This was examined with regard to gender and race categories (Fig. 3).

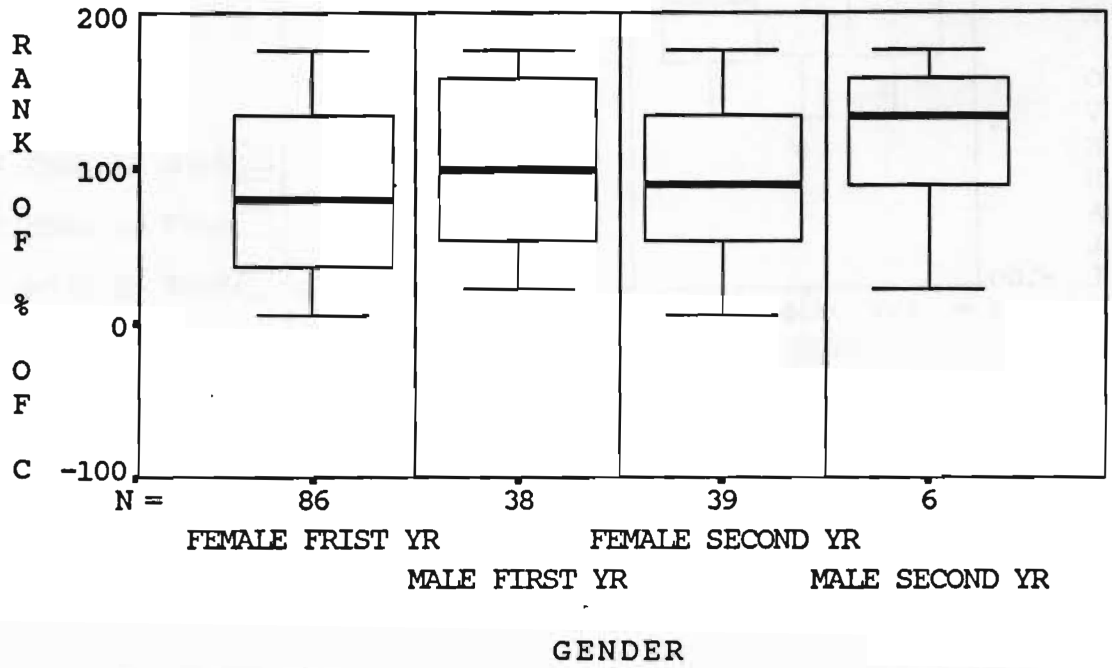

Figure 3. First and second year biology student performance in Part C (folding two dimensional objects into three dimensional ones), showing gender categories.

In tasks involving folding 2D objects into 3D objects (Fig. 3), male first year students had a higher mean rank than their female first year counterparts. Female second year students had a lower mean than male second year students. The male second year students had the highest mean rank even though they clustered more below the 100% mark. These results suggest that male students were better at folding 2D objects into 3D objects than were female students.

In entirety, it can be observed that students in second year performed better than students in first year in all of the three sections of the test (Fig. 4).

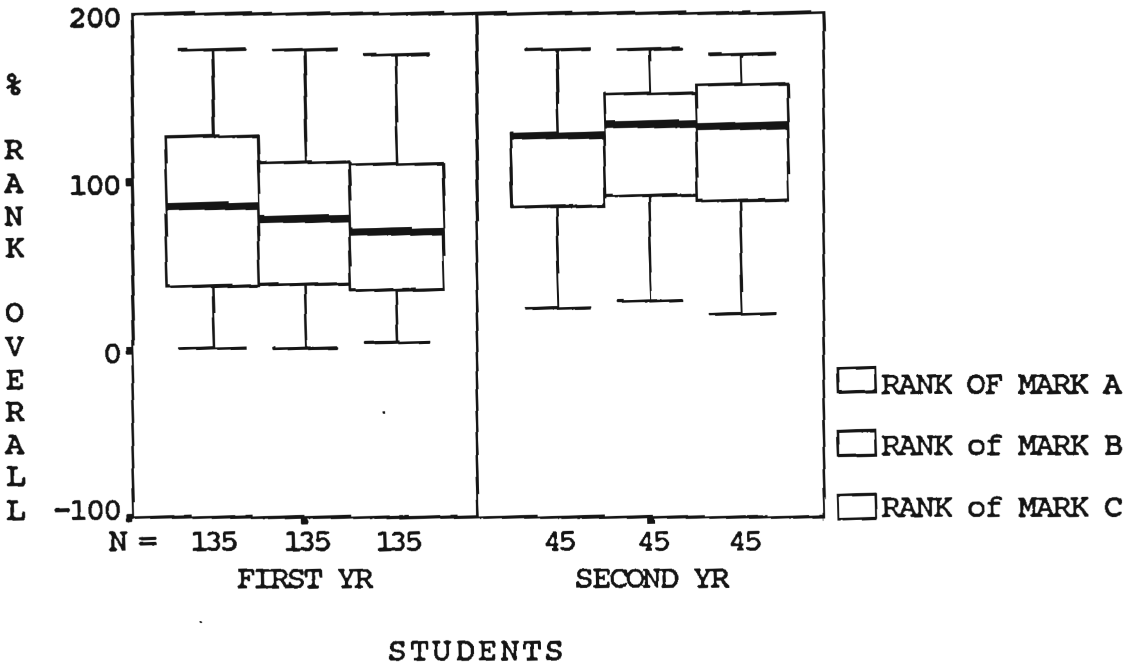

Figure 4. Overall performance of first and second year students, showing Parts A, B, C.

It is observable from Fig. 4 that students of the second year had higher averages in all the three sections of the 2D and 3D tests. First year students had the highest mean rank in Part A, followed by Part B, then Part C. Second year students had a slightly lower mean of rank A as compared to Parts B and C.

Differences within the racial groups were then analysed, using results from the same 3D test (Figs. 5, 6,7).

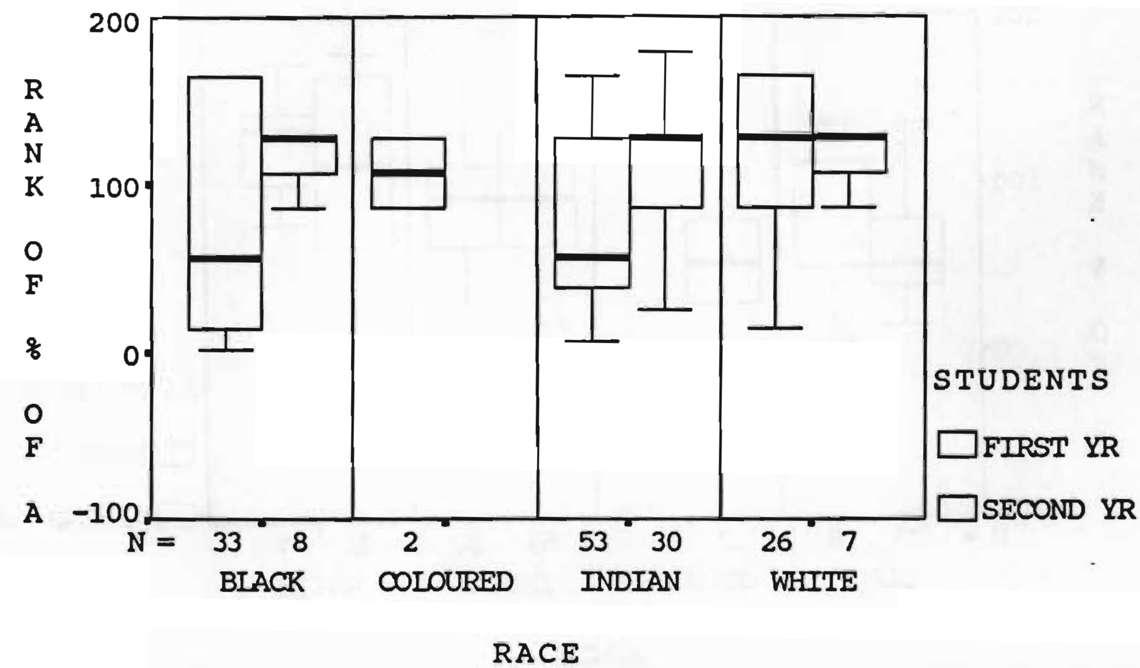

Figure 5. First and second year biology student performance in Part A, showing race categories.

The performance in Part A by second year Black, Indian and White students was similar and better than the performance of most first year students (Fig. 5). However, first year White students had the same mean as second year students. There was no observable difference between the performance of first year Indian and Black students. Since there were no Coloured students in second year, there was no comparison made with other second year race categories. These results suggest that 2D visualization skills (pattern matching) improved as students progressed from first to second year.

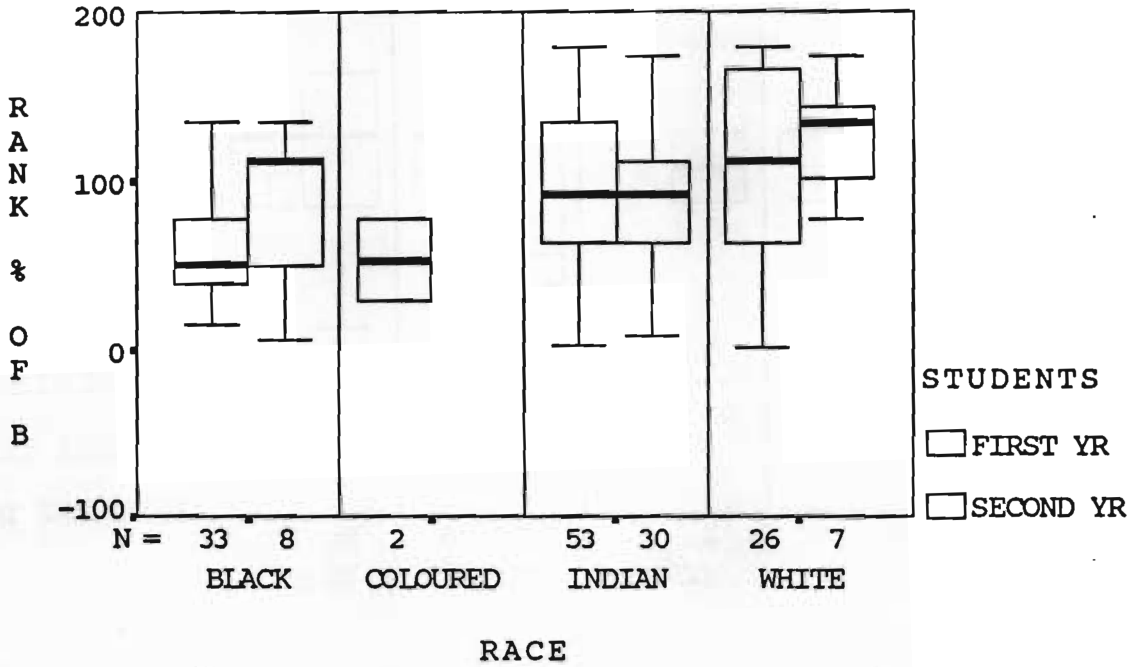

Figure 6. First and second year biology student performance in Part B, showing race categories.

First year Black students had a lower mean than the Black students in the second year (Fig. 6). Indian students of first and second years had the same mean. White students in first year had a lower mean than did White students in second year. 3D visualization skills therefore appear to improve with advance in academic years as both Black and White second year students performed better in this test than did the first year students.

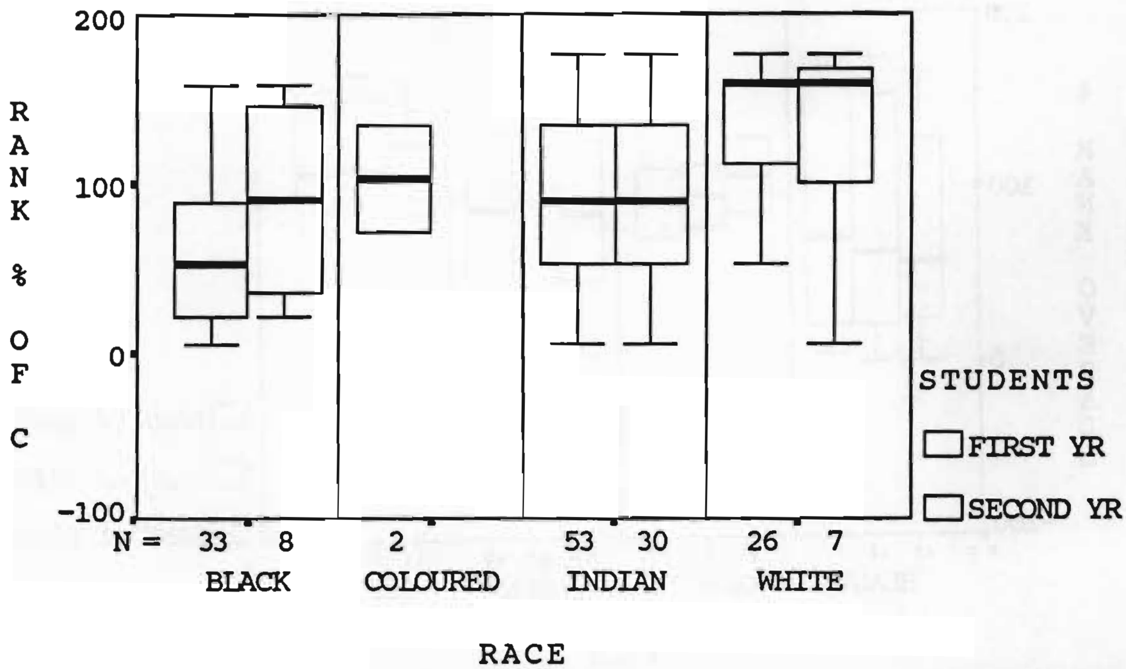

Figure 7. First and second year biology student performance in Part C, showing race categories.

As Fig. 7 shows, Black students in second year had a higher mean compared to Black students in first year. Indian students of both first and second years had the same mean. Likewise, White students of first and second years had the same mean. This was however the highest mean of all in Part C of the test. Length of study appears not to influence the ability of White and Indian students. However, Black students performed better after one year of study.

In all of the sections of the test combined, White students performed better than Coloured, Indian and Black students (Fig. 8).

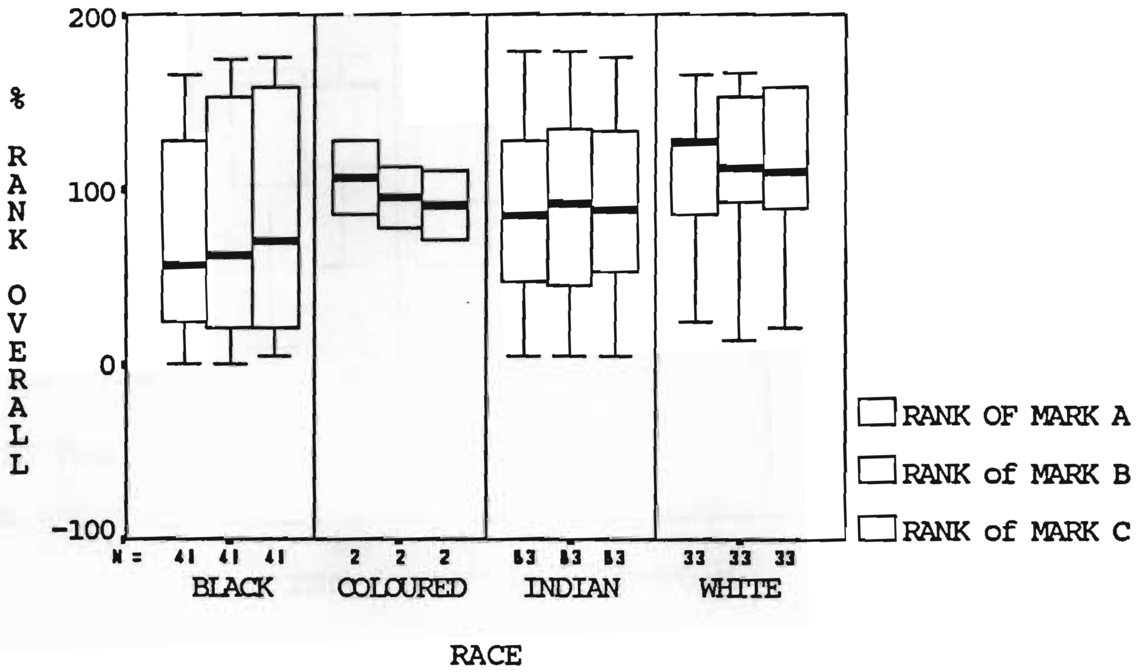

Figure 8. Performance of first and second year students overall, showing race categories.

When the different clusters of students were combined in terms of race categories (Fig. 8), indicates, White students had the highest mean, followed by Coloured, Indian and Black students respectively. Overlaps in particular sections of the test were however notable.

3.3. Results and Discussion

The non parametric Mann-Whitney U - Wilcoxon Test (SPSS) was used to determine statistical differences between students of various racial groups and gender with respect to 3D visual skills (at a confidence/critical level of 0.05).

Analyses of responses related to pattern matching (Part A) showed no significant difference between first year female and male students (p=0.8180), and between second year female and male students (p=0.1192). On the other hand, analysis of Part B showed that male first year students performed better than female first year students (p=0.0052). There was no significant difference between female and male second year students (p=0.1297). Results of Part C showed that female first year students did not perform as well as their male counterparts (p=0.0345). No significant difference was observed between the two gender categories of students in second year (p=0.2890). This finding however did not corroborate media results (Fig. 1), which showed higher means for females than males. This is attributable to the fact that there appeared to be more male students skewed above the mean than female students in the graphical presentation, even though on average, the female students still had higher means. This skewing was however not reflected in statistical analysis, as the numerical result was much higher than the critical level. This could suggest a difference that is not substantial.

Analysis based on the levels of learning and racial groups indicated that there was no significant difference between Black and Coloured students, Black and Indian students, Indian and Coloured students, White and Coloured students in Part A (p=0.5992, 0.4878, and 0.5066, 0.5699 respectively). On the other hand, Black and Indian students did not perform as well as did White students (p=0.0262 and 0.0029 respectively) (Fig. 5). Even though the media results may have shown higher means for first year Coloured students than their Indian and Black counterparts, concentration of students in general seemed to appear above the mean and around the 100% mean rank.

In Part B, there was no significant difference between Black and Coloured students, Coloured and Indian, Coloured and White, White and Indian (p=0.6637, 0.2435, 0.1633, 0.0631 respectively). Black students did not however perform as well as did the Indian (p=0.0263) or White students (p=0.0026) (Fig. 6).

In Part C of the test, there was no significant difference between Black and Coloured students, Coloured and Indian students, Coloured and White students (p=0.2328, 0.7151, 0.2562 for respective groups). However, Indian students performed better than Black students (p=0.0202) but not as well as White students (p=0.0001) (Fig. 7).

Although it has been stereotyped that men perform better than women in most scientific or technical academic activities (Draft White Paper, 1997; Gipson, 1997), results of the 3D test indicate that there is no statistical significance in overall performance between the gender groups in the first and/or the second year Cell Biology class. However, it was observed that female students generally did better than male students in Part A of the test. This involved pattern matching tasks (Fig. 1). This is in line with findings of Colley, Hill, Hill and Jones (1995) that females tend to rate higher than males on attributes that reflect congeniality. This could have been as a result of the widely believed idea that females tend to relate more to aesthetic order than males. Such an attribute within the female gender category could result in higher achievement in tasks relating to pattern matching as opposed to their male counterparts.

The fact that males did better generally compared to females affirms the assertion by Canada and Brusca (1996) that females are prone to perform worse than males in highly competitive environments. Experiments by Colley *et al.* (1995) however dispute this stance as they report that there is no evidence of negative gender stereotyping. These experiments were carried out at the University of Leicester with 150 undergraduates, 108 of who were female. They investigated stereotypes of male and female target figures who had experience of either computer programming, word processing or computer games. Direct empirical evidence that female participation in computing is viewed negatively is lacking, although there is abundant evidence that computing is perceived as a male domain, and boys have been found to rate themselves more favourably than girls in terms of perceived peer reactions to their computer involvement. Sexual connotations may not be relevant or of significance in authoring an educational game as the survey indicated that there was no consequential difference in performance between male and female students.

It was of prime importance to detail students performances based on their level of learning. This was to enable the researcher to propose, or recommend, an effective stage when visualization skills ought to be introduced within the curriculum. This is in line with Maturationist psychological theory of learning as expressed by Fosnot (1996). Maturationism describes conceptual knowledge as dependent on developmental stage of the learner, which in turn is the result of innate biological programming. Learners are thus viewed as active in meaning-making, as they interpret experience with cognitive structures that are of the result of maturation. From this perspective, the educator has the role of preparing an enriched and developmentally appropriate environment.

The curriculum framework should therefore, essentially, delineate requirements of learners matched to their stage of development.

It was observed from this survey that learners in first year did not do as well as their counterparts in second year. From this, it can be inferred that as students undergo all learning experiences within the first year curriculum, they gain and master techniques that relate to their visualization skills. It would therefore be of great benefit to introduce the skills at an early stage within the curriculum in order to develop cognitive abilities related to visualization skills. This is also in line with analysis of findings from interviews with members of academic staff as well as that of prior surveys carried out by Bioped Research Group.

Within the context of South Africa, legacies of the apartheid system of government precipitated preferential treatment of the members of the White fraternity. The aftermath of this was fragmentation and poor articulation of the rights and privileges of the Black majority, race and gender inequalities, constraints on access to major infrastructural facilities (including education) and outmoded curriculum (Hartman *et al.*, 1994; Luckett, 1995). This actuality is corroborated by the Draft White Paper on Higher Education, July, 1997:

"There is an inequitable distribution of access and opportunity for students and staff along lines of race, gender, class and geography. There are gross discrepancies in the participation rates of black and female staff compared to whites and males, and equally untenable disparities between historically black and historically white institutionist in terms of facilities and capacities".

This largely explains the statistical findings that White students appeared to have superior visual skills compared to their Coloured, Indian and Black counterparts (Fig. 7). That the students that did not perform well in the 3D tests are the same ones that came from historically disadvantaged racial groups could be due to the fact that they probably did not have access to basic/essential social/cultural and educational amenities that are crucial in the process of development of 3D visual skills.

The disparity in performance within racial groups is also attributable to differences in cultural backgrounds. Different cultures adopt and follow idiosyncratic socio-cultural trends which may to a large extent enhance or inhibit development of various sense perceptions of individuals to critical functional levels, depending on how they interact with the environment. Certain cultures may as well have reservations or barriers which may negatively reinforce the build-up of innate visual capabilities. In other cultures, for instance, African, most of the written information was portrayed in two dimensions. Also, customs and values were predominantly passed on from one generation to the next orally. This is likely to suppress 3D visualization skills within students of African heritage (Romiszowski, 1988).

In order to redress these past imbalances, Middlehurst *et al.* (1994) suggest that attention should be given to accommodating the educational, linguistic, social and cultural diversity of students. Such are the challenges being addressed by University of Cape Town. Their approach is to evolve flexible degree structures to cater for varied levels of academic preparedness and courses which foster development of skilled and autonomous learners (Hartman *et al.*, 1994). Higgs (1997) of University of South Africa contends that the proposed reconstruction should seek to inculcate a culture of tolerance, accommodation of differences and competing interests. In a similar way, introduction of 3D visualization skills in the Biology curriculum would be a pragmatic attempt to minimize the discrepancies in ability observed in this study. Similar sentiments have been expressed by Lauzon (1999)

3.4. Conclusion

It can be concluded that first and second year Cell Biology students exhibited deficiencies in use of 3D visualization skills. This was also in line with other experiments carried out by members of Bioped Research Unit. Redress was therefore necessary. The most prevalent skills lacking included rotation of 3D images in space, identification of 3D objects projected from 2D images and pattern completion. These would be considered in the design of a learning resource that would be proposed to address them. It also confirmed findings from interviews done with lecturers as the areas of difficulty observed by them concurred with the ones identified from students.

CHAPTER THREE

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1. Introduction to the concepts of games and educational gaming

Many educators and educational researchers are sceptical of the use games in education. The term 'game', or playing games is associated with non-educational ventures and is therefore thought to be undesirable in learning institutions. However, educational research has proved that learning augmented by fun can be more effective (Rieber, 1996; Amory, Naicker, Vincent and Adams , 1999). The fun element here is seen to be derived from playing educational games. Also, research has shown that learning outcomes can be improved when motivational factors are considered within a learning environment. Motivation, both intrinsic and extrinsic, is considered to be a direct advantage of playing games (Quinn, 1994; Sherry & Trigg, 1996). In the wake of the realization that some students need explicit support for knowledge construction, many instructional designers and educators are increasingly considering incorporation of visual illustrations that are offered within gaming activities.

In this chapter, a review of games in educational endeavours is given. An attempt is made to underscore the importance of educational games. Basic game design considerations as well as factors that need to be incorporated within an interactive educational gaming environment are discussed.

The notion of playing a game is not accepted by many people as an educational tool as it is related more to leisure, and meant for children (Randel *et al.*, 1992; Thomas & Macredie, 1994). It should be noted that games require learners to explore and discover the contingencies that guide success and are for that reason construed as constructivist activities. Based on this notion, educational gaming is argued to be useful in the development of psycho-motor, affective and cognitive domains (Rieber, 1996); as well as integration of curriculum knowledge through simulation of the whole educational systems (Betz, 1995).

Games have a long history in various cultures as a vehicle for transmitting societal values such as moral education. Games help mediate between our experience and understanding of the world (Rieber, 1996). Their existence prevails throughout history with roots in our most fundamental practices. The construct of play was so imbedded into humanity, leading to reference of man as "Homo ludens" ("man the player"). Educational games are one of the earliest forms of instructional technology (Rieber, 1996).

Play is part of any gaming situations. Amory *et al.* (1999) point out that the definition of play can be culturally and politically constrained. Generally, play is characterized by such attributes as intrinsic motivation, active engagement, has make-believe qualities and is voluntary (Rieber, 1996; Quinn, 1998). Current theories of play are generally organized around the themes of play being progress, play as power, play as fantasy, and play as self.

Play as progress is the mindset that the purpose of play is to learn something useful, a means of improving psychological or social needs. This type of play is seen as a maturing process whereby children become adults, thereby suggesting a distinction between children's play and adults' play. Play as power refers to competitions where there are those who win and those who lose. Players are in this instance presented with conflict that need to be resolved. Play as power is seen exclusively as a domain for adults. Play as fantasy helps the mind to engage in creative and imaginative thinking. Play as self underscores the need to achieve optimal life experiences through play as an activity (Rieber, 1996; Quinn, 1998). The main issue here is the intrinsic value of an experience and not necessarily learning as an exit outcome.

Simulation and other game types have for a long time been used in certain aspects of education. This trend has however been more prevalent in primary schools as opposed to higher levels of learning. The use of gaming techniques in secondary and further education has featured only recently. In secondary and vocational training, simulation and gaming exercises aimed at developing social skills, or understanding of problems, have been used. In technical training, exercises that train and develop psychomotor skills have also been developed (Randel et al., 1992; Rieber, 1996).

2. Distinction between simulations and games

Even though the terms simulations and games have been used almost simultaneously, it is worth juxtaposing the two concepts in order to identify the dividing line between them. Simulation can be defined as an attempt to give the appearance and/or to give the effect of something else (Rieber, 1996).

An educational simulation requires a model which learners are required to operate, or manipulate, for learning to take place. Usually, the model is a simplified version of the real object, process or system being studied. It is noteworthy that the extent to which the model can be simplified depends on the educational objectives (Quinn, 1994, 1994; Rieber, 1996).

Several types of instructional techniques are commonly classified as simulation, gaming, or a combination of the two. These include aspects such as case studies, role-playing, full simulations, educational games, instructional games and simulation games. Simulation games are learning exercises that combine elements of the full simulation exercises with the competitive element of games. Educational games aim at general educational objectives, that is, basic skills and general knowledge. Instructional games are based on specific objectives that are of a particular real situation. Educational gaming is often considered as a branch of educational simulation. However, there are certain differences. The element of competition that is introduced in games is the most conspicuous distinguishing factor between games and simulations.

This element of competition may either be natural to the realm of study or it may be purposely introduced into learning to make it into a game (Quinn, 1994; Rieber, 1996).

Even though defining the terms simulation and game is a difficult task, there are some general characteristics upon which most designers agree. One similarity is that both simulations and games base activities in imaginary contexts of real-world models. Similarly, both offer the learner control over the activity, even though random variation is always incorporated. A difference that features prominently is that all games include some level of competition; the main objective of the game is to win.

On the other hand, the aim of most simulations is to put the player into a specific role. Another important difference is that games are based on rules which may be defined arbitrarily, whereas simulations are always defined on the dynamic relationships of two or more variables upon which the simulation operates or the underlying model (Romiszowski, 1988; Quinn, 1998).

3. Philosophical and historical basis of plays in education

It is critical to understand the philosophical assumptions of play in order to appreciate its role and value in education. Rieber (1996), for instance, reported that play in public schools has been viewed either as valuable or inconsequential depending on the prevailing political following.

Essentialism, progressivism and existentialism have been the three general educational philosophies that have alternatively dominated policy in public education in time. As the prevailing philosophy in education changes, so does the attitude toward play (Rieber, 1996).

Reflecting on the history of play in America, Rieber (1996) points out that play may be tolerated or encouraged for short periods of time, in the belief that it will act as a motivating strategy. However, play can also be viewed to threaten instructional design efforts when it leads to learning conflicting to outcomes other than those anticipated by the designer (Rieber, 1996).

4. Educational gaming and learning benefits

Educational games can provide learners with experiences and practice closer to the real-life situations than might otherwise be possible in a normal learning situation. They can be designed such as to represent the pressures in real life situations thereby developing learners problem solving skills (Quinn, 1994). Games therefore can help establish how well students are able to apply previously learnt facts, concepts or principles to real life situations. Games also have the advantage of being able to represent reality in a simplified way such that learners can control and respond to certain aspects in life they would otherwise be able to. Learners are also able to be involved in dangerous or threatening situations without physical harm, in a relatively inexpensive way.

A well-designed game can generally involve students intellectually and emotionally in the learning task more than other techniques. Games have also been found to be effective in measuring, changing and reinforcing learners attitudes (Randel *et al.*, 1992; Quinn, 1994).

Games can be applied to a wide range of teaching and learning endeavours even though it may not always be particularly efficient to do so.

Factors that need to be considered include analysis of the situations or skills that are to be learnt, in order to be able to design a realistic model or exercise; and analysis of the learning tasks and difficulties involved, in order to decide the level at which it is necessary to simplify reality (Quinn, 1994).

Games can be used educationally to amplify certain learner aptitudes such as the cognitive, psychomotor, reactive and interactive domains. Regarding the cognitive domain, learners are able to gain conceptual knowledge, using this understanding to explain the phenomenon under study, solve particular problems that involve the phenomenon, and invent new ways of using the phenomenon. In this domain, most games have the two separate functions of transmitting new knowledge and/or the formation and restructuring of conceptual schemata; as well as developing logical thinking, memorization, analytical and creative skills (Quinn, 1994; Rieber, 1996).

Another domain that games help improve is the development of psychomotor objectives. At certain instances, exercises that help develop perception, dexterity, or strength and stamina are presented in the form of games. These exercises may not be related to any specific job situation but are of general use. Use of attitudes and values (the reactive domain) is another objective of games that should culminate in change of attitude or new values.

The experience here also involves development of self-control skills. In the interactive domain, the main objective of games is to develop learner's perceptions of other people's feelings and attitudes, enabling them to interpret reactions and underlying motives therein (Quinn, 1994).

5. Considerations for effective use of educational games

Depending on the category of objectives, different approaches may be employed to the structure of games.

There has been considerable research in educational gaming even though most have been characterized by limited objectives and are thus of little value. Much of the well-designed simulation gaming research has been conducted by the Academic Games Programme at Johns Hopkins University (Quinn, 1994).

Even though evidence that games support affective learning and cognitive skills is uncommon, more convincing evidence of success is available in other areas. Research has suggested that games alter the character of the classroom in a positive manner, by improving motivation of students. A consistent finding is that students and teachers rate games highly as interesting and worthwhile experiences (Randel *et al.*, 1992; Quinn, 1994).

The lack of exploration of pedagogical support in games explains the general lack of emphasis that has been placed on games in general. However, the motivating effects of computer games provide a strong argument for their potential in instruction. Malone (1981, cited by Quinn, 1994) posited three components that contribute to fun in computer games: fantasy, curiosity and challenge. Fantasy is the backbone story on which the game activities revolve. Challenge involves a level of difficulty appropriate to maintain interest throughout the play or over successive games. Curiosity involves having random factors, the element of chance, making the game not predominantly deterministic (Quinn, 1994).

Quinn (1994) also discussed intrinsic and extrinsic forms of motivation. In games where the knowledge activity is independent of the fantasy, the motivation is extrinsic. Quinn (1994, 1998) argued in support of games that were intrinsically motivating, where the fantasy incorporated the learning activity. Such games relate the enjoyment to the learning activity, which is a more desirable outcome. The elemental idea in engagement is the need to consider the flow of activity in meeting an objective, rather than the individual actions. Such an approach provides a level of analysis that is often neglected.

'Immersion' in an activity that has arisen from the 'virtual reality' games is another notion that needs attention. This engages more senses, exclusively, than has been possible in the past (Quinn, 1994, 1998).

Certain issues need to be considered in design and use of a game. For example, it should be established whether the game is likely to be a more effective tool compared to other teaching modes.

Another factor that needs to be considered is whether the game represents reality appropriately, and, it is fun and exciting. If the game does not logically relate to reality, it can possibly lead to misconceptions (Romiszowski, 1988). The extent to which it can be founded on some kind of reality largely depends on the learning objectives. It should also be noted that games require a different kind of teaching technique, and the instructor needs to have professional rationality (Romiszowski, 1988; Rieber, 1996). In general, game design factors that need to be considered include the basic idea and context of the game, style most suitable (for instance level of competition or co-operation) and level of interaction. A decision also needs to be made whether objectives should be made for learners or whether they should make their own. Whether operating instructions for players need to be incorporated into the game is another factor to be considered (Romiszowski, 1988).

6. Characteristics of an interactive learning environment

An effective learning situation needs to be grounded on sound learning theories, consider systems interface design as well as knowledge of what characterizes activities that learner deem entertaining and engrossing (Romiszowski, 1988; Amory *et al.*, 1999).

Most prevalent learning approaches are models that include motivation of the learning by demonstrating the practical applications and importance of the knowledge, providing a conceptual description of the skill, providing practical opportunities with support in the form of scaffolding, and facilitating transfer through guided reflection on the activity to integrate the practical issues with the underlying conception. Justification for the elements of this model include approaches such as problem based learning, cognitive apprenticeship, pragmatic approach, exploration and discovery, and social interaction in learning. The implications of these include induction of the learner into practice which makes the knowledge meaningful, feedback need to be intrinsically embedded into the context in which the activity is performed, the learning challenge should be balanced to match the learner's ability (Romiszowski, 1988).

Interface design need to include action and feedback, in the form of communication, and in the time between action and response. In addition, complex syntax needs to be replaced by direct manipulation on representations that are familiar from other experiences.

The action needs to be designed, meaningfully, for thematic coherence in the temporal development of the experience. Considerable control needs to be in the hands of the player, incorporating options and opportunities for action (Romiszowski, 1988; Randel *et al.*, 1992).

The affective experience of fun is another factor that requires investigation. Malone (1981, cited by Quinn, 1994) proposed three elements of computer games which include fantasy (the scenario in which the activity is embedded); challenge (the level of difficulty); and curiosity (the introduction of new information and non-deterministic outcomes). The level of challenge needs to be matched to learners' skill, characterized by clear goals for the activity (Quinn, 1994; Amory *et al.*, 1999).

However much the notion of exploration and discovery need to be important game design considerations, a degree of learner support is necessary to make games a more engaging activity (Quinn, 1994). There is need to recognize the different learning styles of learners in order to facilitate transfer of knowledge and competencies. The female gender category of students should be of prime consideration as there has been claims of male student dominance in most computer gaming activities (Randel *et al.*, 1992). Cognitively challenging and non-gendered games appeal equally to both male and female groups of learners (Randel *et al.*, 1992; Quinn, 1994).

Development of the game story line is another factor that needs close attention. The story ought to develop out of an embedding theme, at the same time capturing the build up of tension and relief. This notwithstanding, an appropriate level of challenge needs to be maintained (Amory *et al.*, 1999; Quinn, 1998).

Games and the contexts of their use are so robust that it is not easy to control all variables in interplay. Many of the elements that make an activity a game are removed from the inherent nature of the gaming task. Games may not be themselves sufficient for learning to occur, but can provide elements of a learning process such as the activity, as well as motivational aspects of situated learning (Quinn, 1998).

Little attention has been given to the psychological and sociological value of play despite its many advantages to guiding the design of interactive multimedia learning environments for children and adults (Randel *et al.*, 1992). The reasons for the reluctance to include games in education are not clear. Randel *et al.* (1992) attribute this state of affairs to the fact that play is considered the preserve of children and therefore not respectable. Implicit in this is also the fact that play is considered easy and leisurely and can therefore not be used by adults as an educational tool. Play is also usually misconstrued as an irrelevant or inconsequential activity to educational undertakings (Romiszowski, 1988; Randel *et al.*, 1992; Rieber, 1992).

However, the misconceptions are ill placed as educational and psychological research on play has shown that games are important for lifelong learning and socialization.

Games are connected to play in so far as they provide organizational functions related to cognitive, social and cultural aspects within any given learning domain.

Piaget (1977) underscored the importance the functions of play and imitation in the process of equilibration (discussed). Also, anthropologically, games have been viewed as an aspect of expressive culture (Randel *et al.*, 1992; Rieber, 1996; Amory, *et al.*, 1999).

7. Specific design considerations in an interactive educational gaming environment

Playing games is an important part of social and mental development. Experiments carried out revealed that students rated game elements such as logic, memory, visualization and problem solving as important game elements (Amory *et al.*, 1999). Such elements are important to adventure games and could provide sufficient stimulation to engage learners in knowledge discovery, while at the same time developing new skills (Amory *et al.*, 1999).

Computer games enhance learning through visualization, experimentation and creativity of play. The games include tasks that develop critical thinking, the analysis and evaluation of information in order to determine logical steps that lead to concrete conclusions. Visualization plays an important role in discovery and problem solving and is therefore elemental in educational games.

Many of the tasks presented in games involve exploration, goal formation and competition (motivational values) that ultimately stimulate learning and training (Rieber, 1996; Amory *et al.*, 1999).

Educational games are characteristic of aspects that promote educational objectives (abstract) and those that allow for the realization of these objectives (concrete) (Amory *et al.*, 1999; Quinn, 1994). Game spaces therefore consist of either abstract or concrete components that contain discrete interfaces, interfaces that define the interactive learning environment inclusive.

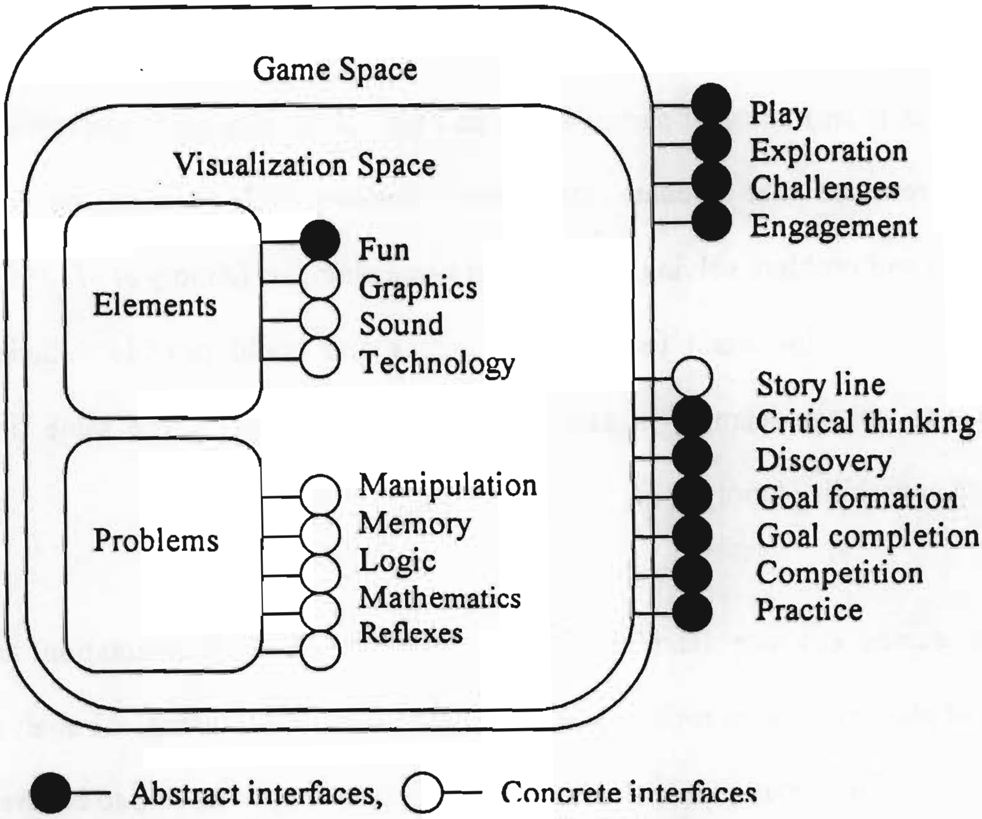

Figure 9. Game development model: components and related interfaces (adapted from Amory *et al.*, 1999, p. 319).

The game space component is proposed by Amory, *et al.* (1999) to consist of four motivational interfaces (play, exploration, challenges and engagement) and the visualization space component which contains the story line, critical thinking, discovery, goal formation, goal completion, competition and practice interfaces (Fig. 9). The elements component contain those interfaces (fun, graphics, sound, and technology) that make up the story line, appearance and ability to play the game, related to the discovery and goal formation interfaces of the visualization space component.

The other interfaces of the visualization space components (critical thinking, discovery, goal formation, goal completion, competition and practice) are expressed through the manipulation, memory, logic, mathematics and reflexes interfaces of the problem component. Abstract interfaces depict pedagogical elements and concrete interfaces depict game elements. Experiments showed students as identifying the two inner-most components (visualization space and problem) and the story line, memory and logic interfaces as the most important game elements.

Such a model could allow for a systematic approach to the development of educational games in line with sound pedagogical considerations (Amory *et al.*, 1999).

8. Shortfalls of gaming situations

Literary evidence in support of educational achievement through participation in games is inconsistent (Rieber, 1996). Affirmative records of results of gaming, especially in comparison to traditional teaching mode, are sparse. The way in which its cognitive and affective attributes of games contribute to learning is yet to be understood by instructional designers. Even though motivation is a necessary in learning, it is not a sufficient condition for learning.

It is also difficult to distinguish between experiential and reflective cognition when describing the role of technology in learning. Experiential cognition is based on reactions to momentary events whereas reflective cognition calls for intricate and deliberate consideration over time. Qualitatively, experience leads to understanding based on a particular task whereas reflection leads to explicit understanding that can be expressed and applied to other problem situations. Educational computer games seem prone to fail to promote reflective cognition (Rieber, 1996). Even though games may provide intrinsically motivating learning environments, steps need to be taken to encourage reflection in order to effect deeper levels of learning that transfer beyond the gaming context itself may not occur.

It is also worth noting that although games may help students to organize content into meaningful patterns and help them set up and monitor learning goals, games may serve to distract students away from learning goals if the gaming activity is particularly intense (Randel *et al.*, 1992; Rieber, 1996).

9. Conclusion

Games are competitive interactions governed by rules to achieve specified goals that depend on skill and often involve chance and an imaginary setting (Randel *et al.*, 1992). Highly motivating games have the characteristic of challenge, fantasy, and curiosity. Because many students enjoy playing games, it has often been an issue of contention whether the play aspect could be combined with instruction to enhance learning. This scenario has led educators to explore the feasibility of using a game format to supplement or replace the teaching of a variety of subjects.

Educators discuss raising student interest with motivating approaches like games, but the educational efficacy of such approaches has not been well documented. Research focused on educational effectiveness of games has been limited. Most recent evaluations of educational software indicate over-indulgence in examination of characteristics of the games rather than learning effects. Learners are bound to gain from contemporary digital technologies that enable instructional game designers to devise pedagogical environments with greater precision.

Features of the game that make it successful should be examined. For instance, it was found that learners prefer games with goals, computer scoring, audio effects, unpredictability and graphics. We need to know what features of games correlate with educational effectiveness (Romiszowski, 1988; Randel *et al.*, 1992).

Randel *et al.* (1992) examined, over a span of 28 years, summaries of research on the effectiveness of games and simulation games in comparison to conventional teaching techniques. Based on this, they drew conclusions and made recommendations: use of games for educational purposes depends on subject matter. For areas where specific objectives can be stated, games can be used. Given the interest that games invoke and allowing for different learning styles or preferences, using games should be considered not only in science disciplines but also in the liberal arts and humanities.

Since games need active participation of students, the material learnt has a greater chance of being integrated into the cognitive structures of the individuals leading to retention and consequent retrieval. Since games have been found to be more interesting than traditional classroom instruction their use is recommended for classes that have motivational problems. For subject areas in which marginal learning effects have been found, instructional games could provide an alternative motivational technique to vary the presentation (Randel *et al.*, 1992; Amory, *et al.*, 1999).

CHAPTER FOUR

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1. Interactive educational game: Introduction

The third phase of the project involved educational game authoring in line with the thesis objectives and tests carried out (p. 1, Chapter 1). Since analyses of previous surveys and prior research findings indicated that learners have functional deficiencies with respect to the use of 3D visualization skills, it was necessary to implement a remedial measure. To achieve this, a computer educational game (Dark Light) was developed by the Bioped research group of which this researcher was a member. In collaboration with the other members of the Bioped research group, the researcher authored the 3D maze as described in Section 2.1 of Chapter 4.

2. Materials and Methods

2.1. Game design considerations

Games are competitive interactions bound by rules to achieve specified goals that depend on skill and often involve chance and an imaginary setting (Randel *et al.*, 1992; Quinn, 1998). Computer games that have educational benefits are characterized by challenge, fantasy, and curiosity. These qualities motivate learners and enable them to acquire problem solving skills.

Randel *et al.* (1992) observe that since many students enjoy playing games, it is contested whether the play aspect could be combined with instruction to enhance learning. Educators of various persuasions have since had to grapple to explore the viability of game formats to either supplement or replace teaching of certain subjects.

Bearing in mind that some scholars and learners have considered games to be a domain of children, with no meaningful educational effects, it was important to thoroughly examine factors that would maximize cognitive benefits.

In this project, the game embodied a 3D maze (Figs. 10 & 11) depicting a scene of virtual reality with a user interface that allowed players to move forward, backward, left, right.

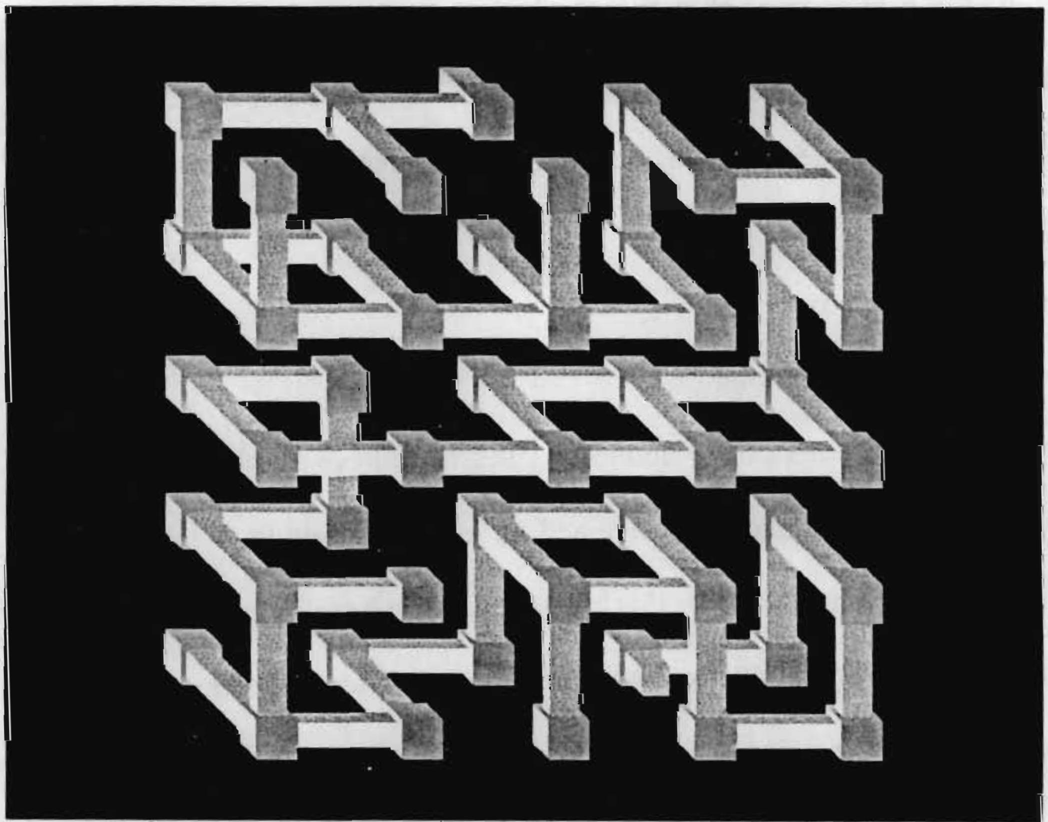


Figure 10. Structure of the 3D maze used in Dark Light, showing the atria (nodes) and passages that connect atria and levels.

3D graphics in the game were created using 3D StudioMax (Kinetix) running under Microsoft NT version 3.5 and 4 on a P166 Pentium processor with 64 MB RAM. Picture editing and additional graphical material was created using PhotoShop (Adobe) or PaintShop Professional (JASC Incorporated). Game creation and playback software was authored to run on the student Local Area Network (LAN) under Window NT 3.11, Windows 95 and Windows 98. Members of bioped created these resources.

Hotspots and interactive inter-phases were added to the game pages depicting the different views within the game. This was done by use of software specially created for this purpose. Each of the graphics files were 'folded' into single game files. Rendering of the graphics was done in millions of colours at 540 by 405 pixels. Each image was then reduced to 256 colours in order to substantially reduce the disc storage space (from 640 KB to 214 KB) when the game files were being created. To store each image, at least 1.25 MB of disc space was needed. The game was then contrived on a computer with a 4 GB SCSI hard drive. In order to store all the different elements in a single file, a game file format was developed, where each of the files accommodated all the images and game logic files related to a single area defined in the initial floor plans (Amory and Vincent, 1998).

2.2. Levels of the game

The game puzzles were based on a 3D structure, consisting of five levels (see Fig. 10), embodying the 2D/3D puzzles. The players navigated their way through the atria, passages and lifts by solving puzzles.

Figure 11. Passage leading to a closed door.

To gain entrance into an atrium, the player must solve a puzzle. Movement between the levels is by lifts associated with some of the atriums. The puzzles were designed in harmony with lecturer's recommendations of various visualization techniques that would enhance 3D visual skills in learners. This was also in agreement with the skills that were discovered to be most in default in learners, as arrived at from analysis of tests and questionnaires presented to them. The puzzles were presented in increasing order of complexity. Each level of the maze contained puzzles related to a single visualization skill.

The learners were also able to navigate their ways by use of elevators and could move in any of the four directions within the atria (east, west, north and south). Background music was also incorporated in the game as this was expected to have a relaxing effect.

Figure 12. Level A puzzle. The squares needed to be rearranged in order to complete the image.

Each level of the game presented the player with a different kind of 2D/3D puzzle. Access to level A interconnecting rooms, or atria, required the player to solve problems related to pattern matching and picture completion (e.g. Figs. 12, 13 & 14). The players needed to click on each of the single bitmaps presented in twenty-five squares randomly, piecing them together in order to complete the patterns. Puzzles at this level related to reconstruction of the random images of picture pieces. On successful completion of this task, the correct image is identified and the player gains access to the next chamber or game level.

Figure 13. Level A puzzle. The random pieces of bitmaps had to be reconstructed to complete the picture.

Puzzles on level B also related to pattern matching. However, these puzzles were designed so that the player first had to identify the correct group in which a 2D structure belonged, and then with this group, identify a pattern made up of the same as identified, but rearranged parts (Fig. 14). The players had to turn on the switches (as in the arrow shown in Fig. 14). Various shapes would then be presented where the player would identify the ones made up of the same lines, pieces or strands as the one presented. Solution to this puzzle would lead to access to the next chamber or level of the game.

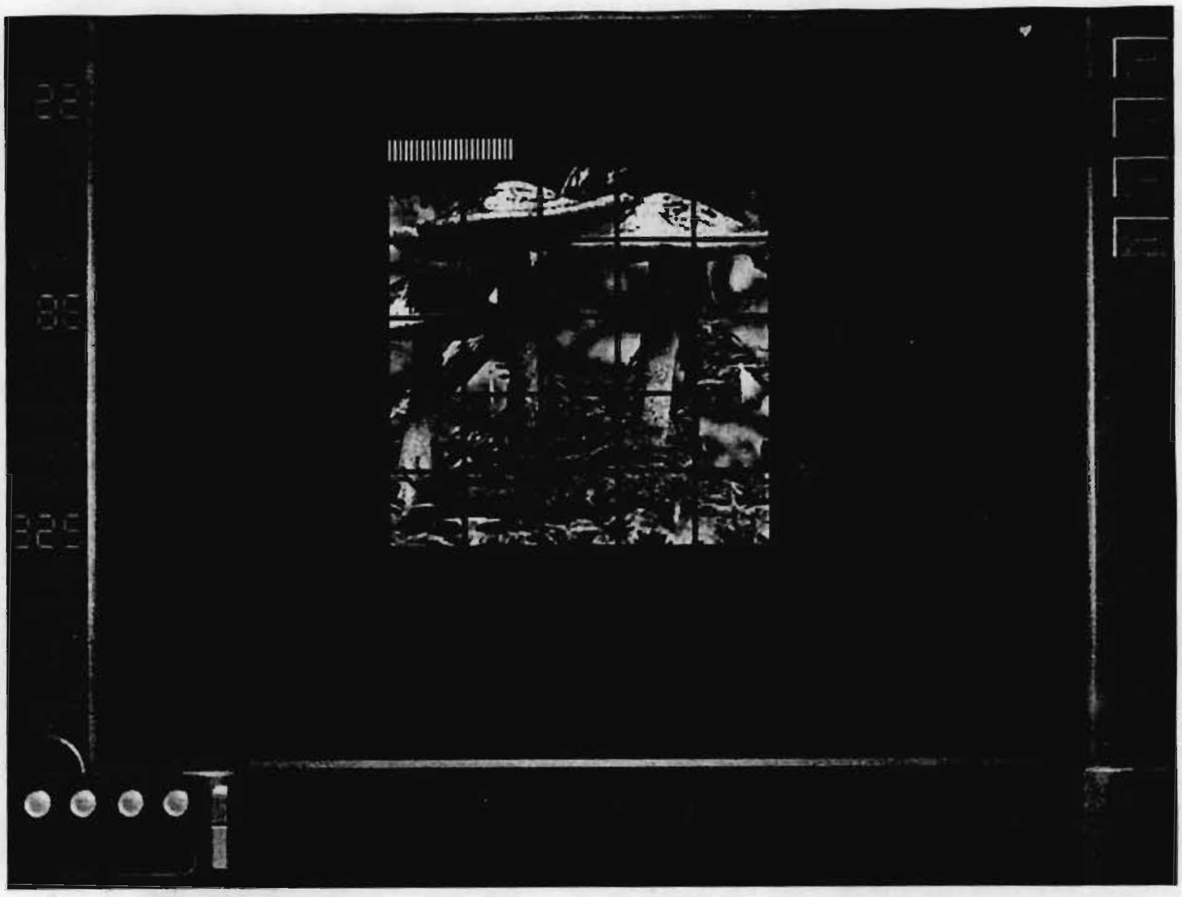


Figure 14. Level A puzzle. Randomly arranged picture pieces had to be put in their correct position in order to obtain a comprehensive image.

Puzzles on the third level required the player to predict 3D objects from front and top views (Fig. 16). Here, the player was presented with randomised 2D figures, in the front and top perspectives. The task here required the player to match the 2D figures presented on the left hand side to corresponding 3D blocks on the right hand side thereby gaining access to the next game level or atrium.

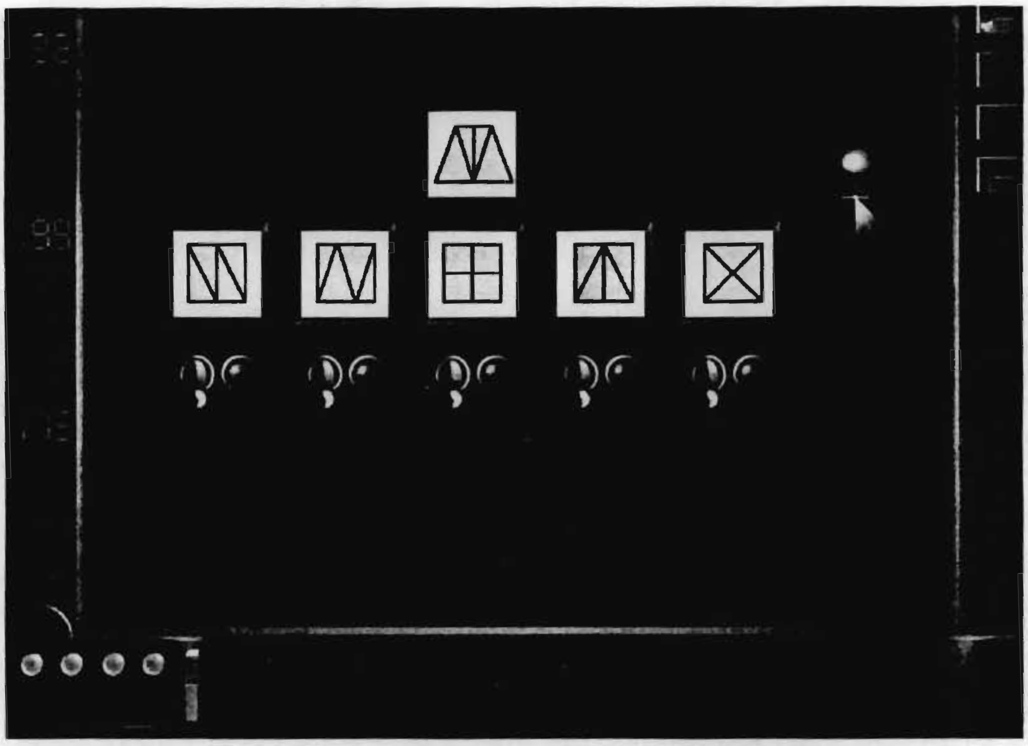


Figure 15. Identification of a 2D structure similar to the one presented.

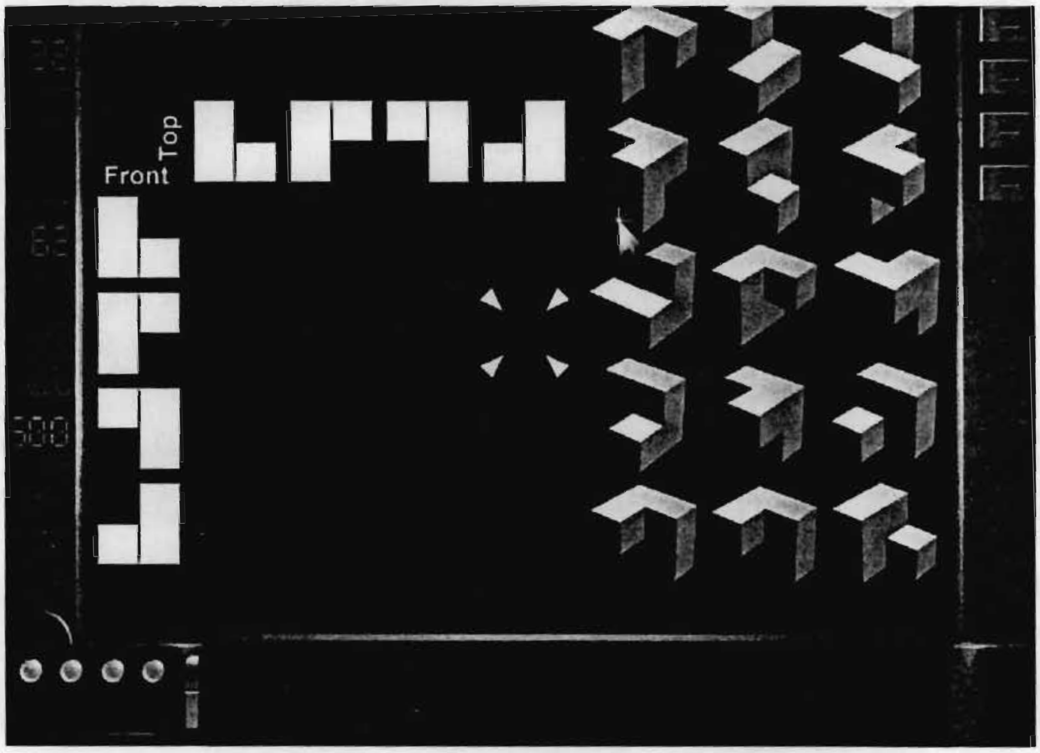


Figure 16. Identification of 3D blocks presented in top and front views.

In the next level, different views of blocks arranged in a 3D pattern had to be selected from a range of 3D objects (Fig. 17). Here, 3D blocks in particular spatial orientations were presented in a different perspective. The player was expected to identify the corresponding blocks thereby solving the task at that level.

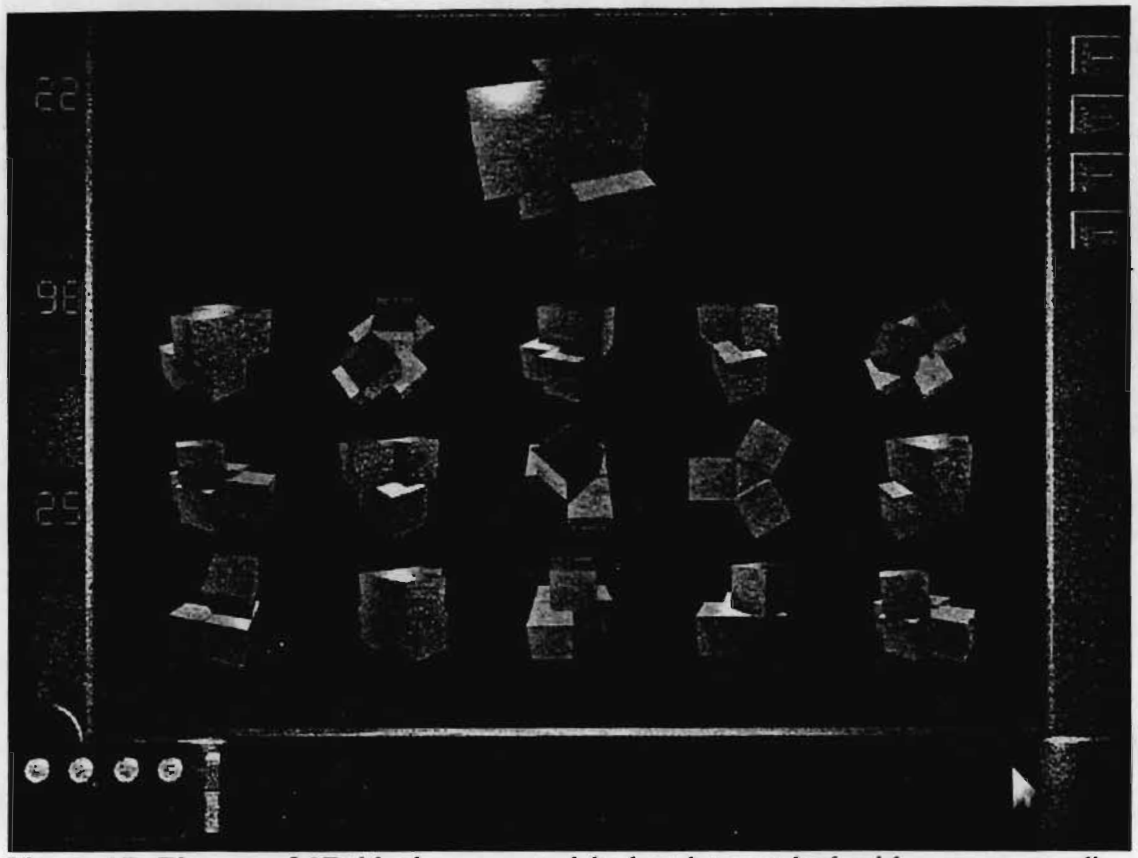


Figure 17. The set of 3D blocks presented had to be matched with a corresponding one from the ones viewed from different angles.

In the last level, the player was presented a 2D object that had to be folded into a 3D object. To solve the puzzle, the player had to select the correct 3D object from a selection of four (Fig. 18). This required the player to mentally fold the 2D figures presented, in order to select the corresponding 3D image. This would enable the player to access the next atrium, eventually being able to solve all the puzzles.

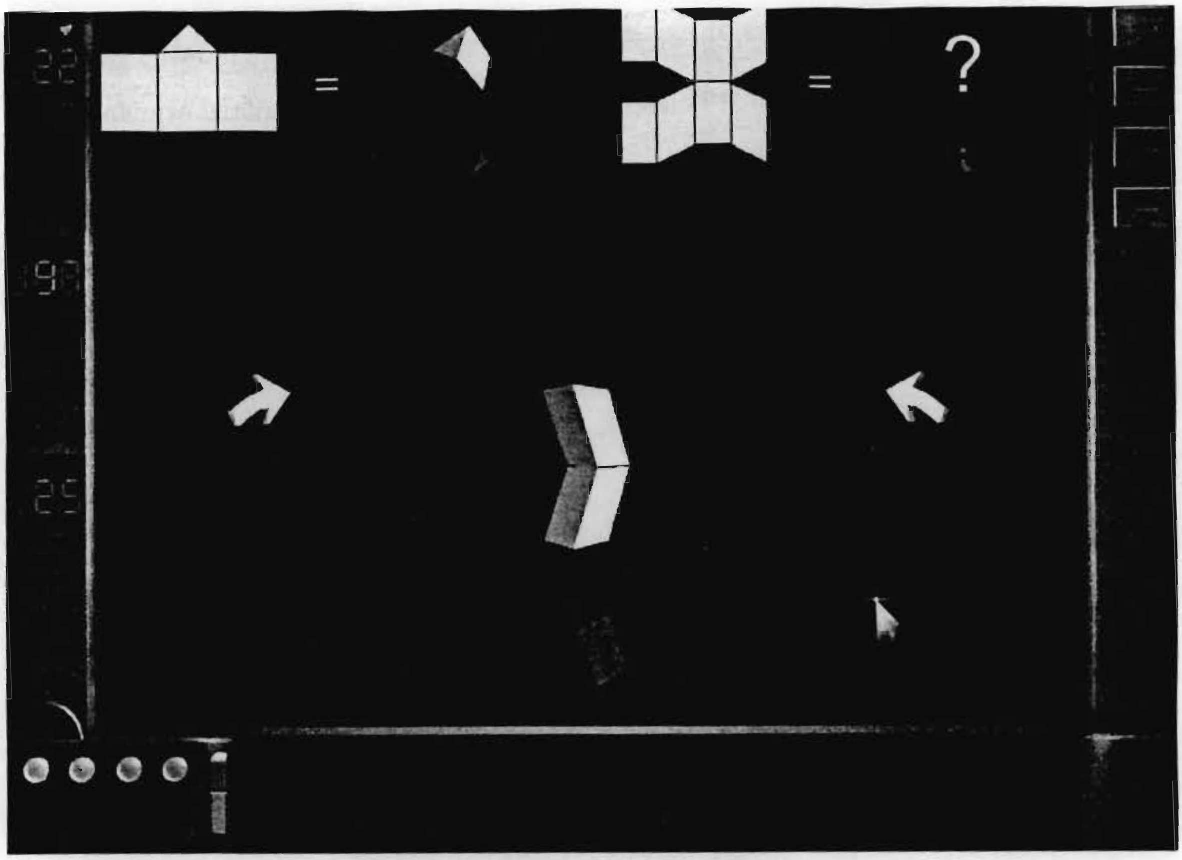


Figure 18. 2D pattern folding to 3D objects.

3. Results and discussion

The design of the learning resource was largely based on Henry Giroux's theory of border crossings[1] and Howard Gardner's theory of multiple intelligences[2] and their educational implications (Giroux, 1992; Gardner, 1993; Lauzon, 1999).

[1] Giroux's notion of border pedagogy refers to the need for a curriculum that would result to representational practices that validate objectivity, universality and consensus.

[2] According to Gardner, a variety of intelligences work in combination in individuals on diverse roles. The seven intelligences proposed by him include linguistic, musical, logical-mathematical, spatial, bodily kinesthetic, intrapersonal and interpersonal. In recent literature, he mentions the possibility of an eighth, the 'naturalist's intelligence'.

Gardner also discussed Lev Vygotsky's concept of "zone of proximal development" which was found useful in intellectual assessment. It refers to the zone between the level of problem solving an individual can do in isolation and the level of problem solving the individual can do in social situations involving more skilful others.

Challenging and appropriate tasks can therefore be designed for good learning situations. Giroux argued that ignoring culture and those students on the margins in the educational enterprise is a result of borders being constructed by those with power, and consequently they include some learners as they exclude others. The challenges for border pedagogy is to help students transgress borders in order to redraw those borders to be more inclusive. In this perspective, Lauzon says that under the right conditions, technology can be used to challenge and transgress the borders. These views were considered and followed closely in the game design.

Randel *et al.* (1992) pointed out the fact that relatively few research studies of the educational effectiveness of games have been conducted. Most of the work on evaluation of games has been anecdotal, descriptive and judgmental.

A literature survey by *Randel et al.* (1992) has showed that since games require active participation of students, the material has a greater chance of being integrated into the cognitive structures of the individuals and thus being retained. This is on the same premise that the game for this survey, Dark Light, was authored.

According to Birnbaum (1982) games, as simulations, are a possible solution to the problem of providing learners with realistic situations structured to reveal significant interactions that lead to focused learning objectives. Essentially, games are interactive, that is, the players react to a planned environment or the action of other players that often result in consequences that call for further action.

The behaviour and consequences of student actions can be observed and critiqued to enable feedback that lead to learning. Another consistent finding is that games and simulations are more interesting than traditional classroom instruction (Romiszowski, 1988; Randel *et al.*, 1992). Gaming situations would be beneficial to classes that have motivational problems. Educational games, such as Dark Light, would vary the subject content as well as presentation through motivational techniques to aid in subjects in which only marginal learning effects have been found.

Summarizing findings of several authors, Randel *et al.* (1992) identify important variables that need to be considered in an educational game authoring exercise: personality, cognitive learning styles, sex of the players, group variables, academic ability and administrative variables.

It is also important to consider game features that would make it successful such as graphics, audio effects, unpredictability, computer scoring, and speed of an answer. These views are heralded by Rieber (1992) who pointed out that instructional applications of micro-worlds conform to the idea of proximal development. Citing Vygotsky (1978, 1986), he explained that, individuals who are on the threshold of learning require external assistance or intervention to reach understanding. Such a learning environment would be provided by games that are contextually functional and performance oriented (Jonassen 1988; Rieber, 1992; Winn, 1993). These issues were considered in the design of Dark Light.

Certain criticisms to Gardner's theory of multiple intelligences (MI) became big challenges to the design of the game. On the application of Gardner's theory, for instance, he has been criticized for not offering a clear programme for educators to use in implementing MI theory in schools. This has led to use of the theory by schools in diverse ways, some ingenious, some less so (Gardner *et al.*, 1996). In his defence, Gardner noted that theories could be put in practice in different ways. In this way, educators are able:

"... to examine their own assumptions about potential and achievement, to consider a variety of approaches to teaching, to try out alternative forms of assessment ... to begin the fundamental kind of self transformation that is necessary if schooling is to improve significantly" (Gardner, 1996, p.582).

This acted as guidance and support to designing a game that was learner centred, tailored to their cognitive needs.

4. Conclusion

As has been observed, learners lack certain critical visualization skills that may adversely affect their intellectual development. This was arrived at from experiments carried out in this project, from review of relevant literature as well as from unpublished surveys undertaken by members of Bioped Research Group. This fact necessitated a remedial measure which was deemed to be able to correct the discrepancies.

The design of the educational game incorporated friendly user interfaces within easily navigable but challenging scenic tasks. Going by modern educational theories that were applicable, such as propounded by Gardner and Giroux, it was possible to design an interactive forum tailored to accommodate learners from different historical backgrounds. This level of flexibility contextualized the learning experience, thereby enhancing an environment that appealed to learners of multiple cultures who had different cognitive styles and preferences. This view was underscored by McLoughlin (1999) and supported by Winn and Jackson (1999).

CHAPTER FIVE

General Conclusions and Recommendations

Restructuring and formulating an innovative curriculum framework obligates a networked commitment between all stake-holders that would be affected by the anticipated changes. In the same line, this project attempted to underscore the close coordination between academic staff and administrators, subject experts and learners to arrive at a consensus in order to incorporate a new component into an existing curriculum (Hartman *et al.*, 1994). A similar approach was adopted successfully at University of Wolverhampton, London in 1993 (Jenkins *et al.*, 1994) even though emphasis here was on independent study by students together with staff-away days. Emphasis of this project was laid on close consultation with students and lecturers while identifying visualization problems that learners have and designing a computer based educational game to address these problems.

The study was carried out in three steps. In the first part, after review of relevant literature and familiarization with curriculum frameworks pertinent with objectives of the project, qualitative interviews were carried out with lecturers within the Department of Biology. This was to point out conceptual problem areas of learners and propose remedial actions in line with CBE and constructivist principles.

The second part involved testing of 3D skills in first and second year Cell Biology students via questionnaires. The aim of this part of the study was to specifically determine visual skills that were lacking and could consequently be remediated. The third part involved design of computer generated educational game (Dark Light). This, and such exercises as would help augment learners' visual perceptions would ultimately be incorporated in to the curriculum, after evaluating the impact.

This study proposed that there is a need to re-consider our assumptions about educational practice. Learning is seen to be constructed as a process of enculturation whereby appropriate skills, knowledge, beliefs, and values are acquired through participation in a learner centred environment (Lauzon, 1999). This constructivist approach should however be carried out in conjunction with (traditional) instructivism so as to accommodate interpersonal and intrapersonal learner needs.

Approaches to instructional design within the context of mediated education ought to consider a curriculum framework that is suitable. Technology, especially computers, if used in the right way, can lead to improved educational standards. CBE should therefore not be used in isolation, but should be supplemented with other interactive media resources. Conclusively, the educational computer game (Dark Light) designed in this project appeared to be having a positive effect in increasing learner perception of concepts otherwise incomprehensible.

Based on a constructivist approach and sound curriculum considerations, CBE can be a useful resource, and can help mitigate, or ameliorate, some of the current quagmires imminent in the educational and socio-economic sectors. As noted by Canada *et al.* (1996), inequalities tend to appear along gender lines as well. Male students and students from high socio-economic status backgrounds are well positioned to do better than female students and students from low socio-economic backgrounds. Of fundamental importance, therefore, in formulating a curriculum framework, is to make learning relevant both to demands of the contemporary world and expectations of learners, sensitive enough to accommodate different cultural, economic and racial backgrounds, as well as sexual orientations. To balance this ambition and come up with a consensus within the whole concentration involved in education may not be an easy task (Rogers, 1997).

Another implication of this study is that visualization skills, particularly orientation and rotation of 2D and 3D images in space, are necessary for improvement of academic standards and should be incorporated into the curriculum. Even though remedial cases were identified (that is, learners who did not perform well in the tests), it is suggested that the skills be introduced to all of the students in the first year of the undergraduate programme. This is because even learners who did well altogether may not have done well in all aspects of 3D visual skills.

Assessment of the use of the educational software (Dark Light) developed in this project is also recommended. It's application, as a solution to the lack of 3D perceptual skills among students would appear to be having a positive effect.

However, in order to make a conclusion on its effectiveness in informing students' learning, a formal evaluation of the tool needs to be undertaken.

It is also recommended that more deliberate research aimed at establishing gender and race differences with regard to 3D visualization skills should be carried out. This would form a basis for mediated educational resources specially toned to cater for learners of different racial backgrounds. Similarly, the influence of rural and urban environments on visualization skills in learners needs to be examined. Further, it would be useful to assess performance of students on CBE activities to determine the impact of computer based learning environments, in conjunction with the instructivist mode, and in line with constructivist philosophy. A milieu that would lead to dual and complementary use of the two approaches needs to be established to improve the quality of education.

References

Amory, A. (1997). Integration of technology into education: theories, technology, examples and recommendations, Contract Report, *Open Society Foundation of South Africa*, Open Society Foundation of South Africa, Cape Town.

Amory, A. and Vincent, J. (1998). Game development diary: Lessons learnt in developing an interactive teaching game, (ed. le Roux, A.), *Media for the new millenium: looking into the future, Educational Media Institute (EMI) of the South African Association for Research and Development in Higher Education (SAARDHE)*, 221-225, Pretoria.

Amory, A., Naicker, K., Vincent, J. and Adams, C. (1999). The use of computer games as an educational tool: identification of appropriate game types and game elements, *British Journal of Educational Technology*, **30**(4): 311-321.

Ausbel, D. (1968). Educational Psychology, Holt, Rinehart and Winston, New York.

Banaka, W. H. (1971). Training in depth interviewing, Harper and Row, New York.

Barker, P. and Wisker, G. (Eds.) (1997). Tools to support electronic lectures, *Educational Technology Research and development*, **34**(1): 245-250.

Beijnath, N. and Hendricks, C. (1993). Review, reform and reflection: changing the political studies curriculum, AD Dialogues.

Betz, J. A. (1995). Computer games: Increase learning in an interactive multidisciplinary environment, Journal of Educational Technology Systems, 24(2): 195-204.

Birnbaum, R. (1982). Games and simulations in higher education, *Simulations and Games*, **13**(l): 3 -9.

Black, T. R. (1993). Evaluating Social Science Research: An Introduction, Sage Publications, London.

Blignaut, J. (1996). Information Technology (IT) - A must for education, *Informedia, Journal of the national film library*, **43**(1): 2-3.

Brodlie, K. W., Carpenter, L. A., Earnshaw, R. A., Gallop, J. R., Hobbold, R. J., Mumford, A. M., Osland, C. D. and Querendon, P. (Eds.) (1992). Scientific Visualization, Springer-Verlag, New York.

Canada, K. and Brusca, F. (I 996). The technological gender gap: evidence and recommendations for educators and computer-based instruction designers, *Educational Technology Research and Development*, **39**(2): 43 -51.

Carey, D. M. (I 993). Teacher roles and technology integration: moving from teacher as director to teacher as facilitator, *Computers in the Schools*, 9(2/3): 105-114.

Cohen, C. and Manion, L. (1985). Research methods in education, Croom Helm, London.

Colley, A., Hill, F., Hill, J. and Jones, A. (I 995). Gender effects in the stereotyping of those with different kinds of computing experience, *Journal of Educational Computing Research*, **12**: 19-27.

Collins, A. (1991). The role of computer technology in restructuring schools. *Phi Delta Kappan*, 28-35.

Collis, B. (1989). Computers, curriculum, and whole-class instruction: issues and ideas, Wadsworth, Belmont.

Creswell, J. W. (1998). Qualitative inquiry and research design, Sage Publications, London.

Daily Nation on the Web, Wednesday, 24th June, 1998.

Davies, K. I. (1976). Objectives in curriculum design, McGraw-Hill, London.

Dede, C. (1995). The evolution of constructivist learning environments: immersion in distributed virtual worlds, *Educational Technology*, **35**(5): 46-51.

Dey, I. (1993). Qualitative data analysis: A user friendly guide for social scientists, Routledge, London.

Dick, W. and Carey, L. (1990). The systematic design of instruction, Scott, Foresman, Glenview, Illinois.

Draft White Paper on Higher Education, Department of Education, 24 July, 1997 (http://www.polity.org…te-papers/highed.html).

Driel, J. N. V. and Davies, J. C. (Eds.) (1989). Digital geological and geographic information systems, American geophysical union, Washington.

Fosnot, C. T. (Ed.) (1996). Constructivism: theory, perspectives and practice, Teachers college Press, New York.

Friedhoff, R. M. and Benzon, W. (1988). Visualization, W.H. Freeman and Company, New York.

Gagne, R. M. (1985). The conditions of learning and theory of instruction, Holt, Rinehart and Winston, New York.

Gardner, H. (I 993). *Multiple Intelligences. The Theory in Practice*, Harper Collins, New York.

Gardner, H., Kornhaber, M. L. and Wake, W. K. (1996). Intelligence: Multiple perspectives, Harcourt Brace College Publications, Fort Worth.

Gipson, J. (1997). Girls and computer technology: Barrier or key? *Educational Technology*, 35(2): 41-42.

Giroux, H. (1992). Border crossings: Cultural workers and the politics of education, Routledge, New York.

Glaser, R. (1991). The maturing of the relationship between the science of learning and cognition and educational practices, *Learning and Instruction*, **1**: 129-144.

Greening, T. (1998). Building the constructivist Toolbox: An exploration of cognitive

Technologies, *Educational Technology*, **38**(2): 23-33.

Grundy, S. (1987). Curriculum: product or praxis, Falmer Press, London.

Hannafin, M. H., Dalton, D. W. and Hooper, S. (1987). Computers in education: Ten myths and Ten needs, *Educational Technology Research and Development,* **27**(10): 8-14.

Hannafin, M. J. (1992). Emerging technologies, instructional system design and learning environments: Critical perspectives, *Educational Technology Research and Development*, **40**: 49-64.

Harper, D. O. (1987). The creation and development of educational computer technology, *Educational Technology,* **4**:39-45.

Hartman, N. and Warren, D. (1994). Perspectives on a framework for curriculum development created for use in the faculty of Social Science and Humanities at the University of Cape Town, *SAAAD Conference*, 234-254.

Hearnshaw, H. M. and Unwin, D. J. (Eds.) (1994). Visualization in the Geographic information systems, John Wiley and sons, Chichester.

Higgs, P. (1997). Towards the reconstruction of a philosophy for educational discourse in South African higher education, *South African Journal of Higher Education*, **11**(2): 10-11.

House, E. R. (1979). Technology versus craft: A ten year perspective on innovation, *Curriculum Studies in the last Decade, Journal of Curriculum Studies*, **11**(1): 1-15.

Jenkins, A. and Walker, W. (Eds.) (1994). Developing student capacity through modular courses, Kogan Page, London.

Jensen, M. (1999). African Internet Status (http://www3.sn.apc.org/africa/afstat.htm).

Jonassen, D. H. (1988). Designing structured hypertext and structuring access to hypertext, *Educational Technology*, **28**(11): 13-15.

Kolb, D. A. (1984). Experiential learning: experience as a source of learning and development, Prentice-Hall, Englewood Cliffs, New Jersey.

Krueger, R. A. (1988). Focus groups, a practical guide for applied research, Sage, London.

Kozma, R. B. (1987). The implications of cognitive psychology for computer based learning tools, *Educational Technology*, **27**(11): 20-25.

Lauzon, A. C. (1999). Situating cognition and crossing borders: resisting the hegemony of mediated education, accommodating issues of culture and diversity in the application of new technologies, *British Journal of Educational Technology*, **30** (3): 261-276.

Luckett, K. (1995). Towards a model of curriculum development for the University of Natal's Curriculum reform programme, *Academic Development*, **2**(128): 127-128.

Mayer, R. (1984). Aids to text comprehension, *Educational psychologist*, **19**: 30-34.

McKim, R. H. (1980). Experiences in Visual Thinking, Second Edition, PWS Engineering, Boston.

McLoughlin, C. (1999). Culturally responsive technology use: developing an on-line community of learners, *British Journal of Educational Technology*, **30**(3): 231-232.

Middlehurst, R. and Barnett, R. (1994). In Bocock, J. and Watson, D. (1994). Managing the University Curriculum: Making common cause, Open University Press, Buckigham, UK.

Mwamwenda, T. S. (1989). Educational psychology: an African perspective, Butterworths, Durban.

Moore, T. W. (1974). Educational theory: an introduction, Routledge and Kegan Paul, London.

Owen, G. S. (1993). Visualization Education in the USA, *Journal of Computers and Education*, **8:** 339-345 (http://www.cs.gsu.edu/mathcsc/research/papers/vised.html).

Patton, M. Q. (1980). Qualitative evaluation methods, Sage Publications, London.

Piaget, J. (1977). The grasp of consciousness: action and concept in the growing child, Routledge and Kegan Paul, London.

Popkewitz, T. S. (1984). Paradigm and ideology in educational research, Falmer Press, London.

Qiunn, C. N. (1994). Designing educational computer games, (Eds. Beattie, K., McNaught, C. and Wills, S.) *Designing for change in teaching and learning (A-59),* Elsevier Science B. V., North-Holland.

Quinn, C. N. (1998). Engaging in learning. *In* http://itech1.coe.uga.edu/itforum/paper18/paper18.html

Randel, J. M., Morris, B. A., Wetzel, C. D. and Whitehill, B. V. (1992). The effectiveness of Games for Educational Purposes: A review of Recent Research. *Simulation and Gaming*. Sage Publications, Newsbury Park, **23**(3): 261-273.

Reed, S. K. (1973). Psychological processes in pattern recognition, Academic Press, London.

Rieber, L. P. (1992). Computer-based microworlds: a bridge between constructivism and direct instruction, *Educational Technology Research and Development* **40**(l): 93-104.

Rieber, L. P. (1995). A historical review of visualisation in human cognition, *Educational Technology Research and Development* **43**(l): 45-55.

Rieber, L. P. (1996). Seriously considering play: designing interactive learning environments based on the blending of microworlds, simulations and games, *Educational Technology Research and Development* **44**(2): 43 -5 8.

Rogers, B. (1997). Informing the shape of the curriculum: new views of knowledge and its representation in schooling, *Curriculum Studies*, **29**(6): 684-685.

Romiszowski, A. J. (1988). The selection and use of Instructional Media, Kogan Page, London.

Saye, J. (1997). Technology and educational empowerment: students perspectives, *Educational Technology and research development*, **45**(2): 6-7.

Scott, P., Dyson, T. and Gater, S. (1987). A constructivist view of learning and teaching in science, Leeds, *Centre for Studies in Science and Mathematics Education*, University of Leeds, 73-91.

Sherry, L. and Trigg, M. (1996). Epistemic forms and epistemic games, *Educational Technology*, **36**(1): 38-44.

Schubert, W. H. (1986). Curriculum: perspective, paradigm, and possibility, Macmillan, New York.

Schwebel, M. and Ralph, J. (Eds.) (1974). Piaget in the classroom, Routledge and Kegan Paul, London.

Sprinthall, N. A. and Sprinthall, R. C. (1990). Educational psychology, a developmental approach, McGraw-Hill, New York.

Taylor, D. R. (Ed.) (1991). Geographic information systems, the microcomputer and modern cartography, Pergamon Press, Oxford.

Tesch, R. (1990). Qualitative research: Analysis Types and software tools, Falmer, London.

Rieber, L. P. (1996). Seriously considering play: designing interactive learning environments based on the blending of microworlds, simulations and games, *Educational Technology Research and Development* 44(2): 43 -5 8.

Rogers, B. (1997). Informing the shape of the curriculum: new views of knowledge and its representation in schooling, *Curriculum Studies*, 29(6): 684-685.

Romiszowski, A. J. (1988). The selection and use of Instructional Media, Kogan Page, London.

Saye, J. (1997). Technology and educational empowerment: students perspectives, *Educational Technology and research development*, 45(2): 6-7.

Scott, P., Dyson, T. and Gater, S. (1987). A constructivist view of learning and teaching in science, Leeds, *Centre for Studies in Science and Mathematics Education*, University of Leeds, 73-91.

Sherry, L. and Trigg, M. (1996). Epistemic forms and epistemic games, *Educational Technology*, 36(1): 38-44.

Schubert, W. H. (1986). Curriculum: perspective, paradigm, and possibility, Macmillan, New York.

Schwebel, M. and Ralph, J. (Eds.) (1974). Piaget in the classroom, Routledge and Kegan Paul, London.

Sprinthall, N. A. and Sprinthall, R. C. (1990). Educational psychology, a developmental approach, McGraw-Hill, New York.

Taylor, D. R. (Ed.) (1991). Geographic information systems, the microcomputer and modern cartography, Pergamon Press, Oxford.

Tesch, R. (1990). Qualitative research: Analysis Types and software tools, Falmer, London.

Thomas, P. and Macredie, R. (1994). Games and the design of human computer interfaces, *Educational Technology Training and Innovations*, **31**(2): 134-142.

Uhr, L. (1973). Pattern recognition, learning and thought, Prentice-Hall, New Jersey.

Underwood, J. D. M. and Underwood, G. (1990). Computers and learning: helping children acquire thinking skills, Blackwell, Oxford.

Vernon, M. D. (1970). Perception through experience, Methuen and Company, London.

Welsh, J. A. (1993). Symposium on evaluation of educational software, Virginia Commonwealth University, Richmond.

Wexelblat, A. (Ed.) (1993). Virtual reality: applications and explorations, Academic press, Boston.

White, J. A. and Purdom, D. M. (1996). Viewing modem instructional technology through conceptions of the curriculum, *Educational Technology Review*, **6**: 5-9.

Winn, W. (1993). Instructional design and situated learning: paradox or partnership? *Educational Technology*, **33**(3): 16-21.

Winn, W. and Jackson, R. (1999). Fourteen propositions about educational uses of virtual reality, *Educational Technology*, **39**(4): 5-13.

Appendix 1: Interview questions developed to find out convictions and experiences of university lecturers on visualization techniques

Visualization skills incorporation into an undergraduate biology curriculum

The objective of the BIOPED research group is to be able to determine, design and develop instructional resources aimed at improving teaching and learning processes that can incorporate Computer Based Education. In light of this, I request an interview to solicit information about 3D Visualization skills in teaching and learning. Please, reply, indicating date, time and place convenient to you for the session that would take a maximum of 30 minutes.

Find attached brief explanations to some visualization concepts and the open-ended questions that would guide us through the interview. Note that for purposes of qualitative analysis, the interview will be audio-taped. However, strict confidentiality shall be observed and anonymity provided, if so desired, when reporting findings. Thank you in advance.

3D Visualization skills incorporation in a biology undergraduate course

Visualization is a tool, or method, used to interpret image data and for generating images from complex multi-dimensional data sets. It is the skill that can be used to find fresh solutions to problems or to create new and original ideas. The goal of visualization is to represent data in graphical or pictorial forms that engage the sensory system. Visualization skills include:

Pattern recognition: Is a many-to-one mapping from the set of all the variant instances of the different patterns that can be identified to the set of these patterns names. Some theoretical approaches to the problem of pattern recognition are 'template matching' where new input is compared to a standard and 'feature analysis' where the presence of particular parts of a pattern is decisive.

Linear transformation: Refers to the process where a rigid object is moved in space thereby changing the point of view. Other linear transformations include rotation, magnification, reflection (mirror image).

Orientation of form: Identification is rather more difficult with objects which are perpetually perceived in one particular orientation, for example, the upright position.

For instance, pictures of real objects, when turned through 90 degrees, with all surroundings obscured, could be identified in only 15% of cases, as compared with 66% when they were upright. Meaningless shapes are liable to appear different when orientation is varied. Also, it is more difficult to recognize shapes such as letters, which have been learnt in one particular orientation, when displayed in other orientations.

Spatial framework and perception of distance: The greater the similarity between two patterns, the less should be the distance between the patterns when they are represented as points in a multi-dimensional space. Differences in brightness between different parts of an object may contribute, as 'shadows' to the impression of three-dimensionality. The receding sides of a solid object, and any part of its surface in relief, tend to be shadowed on the side away from the direction of illumination. By changing light direction it is possible to produce a change in the appearance of relief. Objects equally illuminated from all sides lose their three-dimensional appearance and be perceived as flat.

Selective emphasis: Allows the detection of previously hidden patterns by highlighting certain features of the data and suppressing others.

Transformation: Non-visual data can be transformed into visual images by mapping data values into visual characteristics.

Contextualization: Involves providing a visual context or framework within which the data may be displayed and interpreted.

3D visualization skills incorporation in biology undergraduate course: university lecturers interview

This interview seeks to obtain information and insights from university lecturers concerning their opinions and convictions about use of 3D visualization skills in teaching and learning. The ultimate goal is to design educational resources and strategies that are possibly more effective and embrace Computer Based Education. Your involvement in the project is invaluable and will take us a long way in realizing the goal.

Interview Questions:

1) Are visualization skills/techniques necessary to aid instruction in topics you teach?

2) Do your courses require visualization skills? If so, could you define the types of visualization skills you think your students require? FOR EXAMPLE, pattern folding (projecting 2D material into 3D objects); orientation of form (identifying 3D objects that are oriented differently); rotation (identifying 3D objects from top and front views); pattern matching (identifying objects that are rearranged); pattern completion (arranging images to form a full picture).

3) Do students have a grasp of visualization concepts/techniques in topics you teach?

4) Do students exhibit improved/changing levels of visualization skills with age or advance in levels of learning?

5) Are there variations in levels of grasp of visualization techniques in learners of different racial backgrounds?

6) Do you think teaching of visualization skills is transferable and would aid instruction in topics you teach?

7) Should all students learn some visualization concepts?

8) Should visualization techniques be a part of Biology course or should there be a separate course in the area?

9) At what stage of the Biology course should visualization concepts be introduced?

10) What sorts of exercises do you think should be included in the course to improve visualization skills?

Thank you for your cooperation.

--

Contact: amory@biology.und.ac.za, osodo@biology.und.ac.za

Appendix 2: Questionnaire used for testing three-dimensionality and visualization skills in students

ANSWER SHEET

Gender________________________________ Race________________________________

PART A

1.	~~A~~	B	C	D	E
2.	A	B	C	D	E
3.	A	B	C	D	E
4.	A	B	C	D	E
5.	A	B	C	D	E
6.	A	B	C	D	E
7.	A	B	C	D	E
8.	A	B	C	D	E
9.	A	B	C	D	E
10.	A	B	C	D	E

PART B

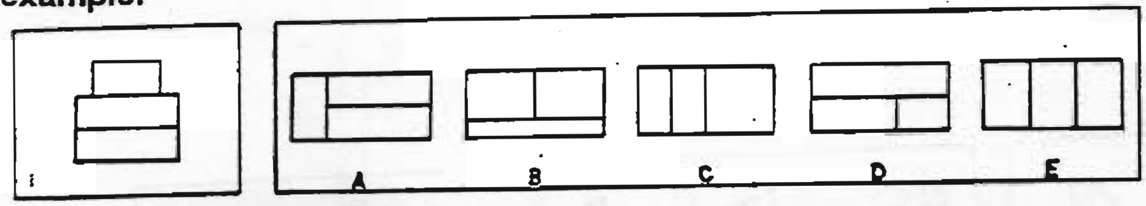
11.	A	~~B~~	C	D	E
12.	A	B	C	D	E
13.	A	B	C	D	E
14.	A	B	C	D	E
15.	A	B	C	D	E
16.	A	B	C	D	E
17.	A	B	C	D	E
18.	A	B	C	D	E
19.	A	B	C	D	E
20.	A	B	C	D	E
21.	A	B	C	D	E
22.	A	B	C	D	E
23.	A	B	C	D	E
24.	A	B	C	D	E
25.	A	B	C	D	E
26.	A	B	C	D	E
27.	A	B	C	D	E
28.	A	B	C	D	E
29.	A	B	C	D	E
30.	A	B	C	D	E
31.	A	B	C	D	E
32.	A	B	C	D	E
33.	A	B	C	D	E
34.	A	B	C	D	E

PART C

35.	~~A~~	B	C	D
36.	A	B	C	D
37.	A	B	C	D
38.	A	B	C	D
39.	A	B	C	D
40.	A	B	C	D
41.	A	B	C	D
42.	A	B	C	D
43.	A	B	C	D
44.	A	B	C	D
45.	A	B	C	D

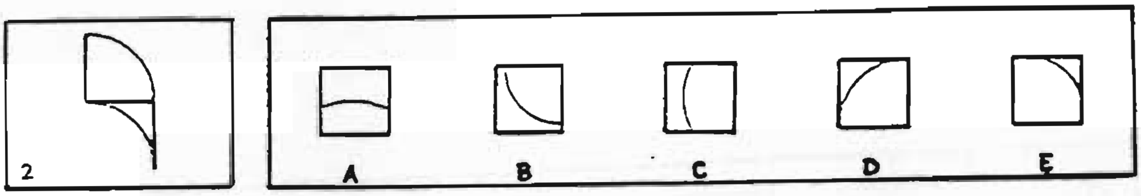
PART A
INSTRUCTIONS

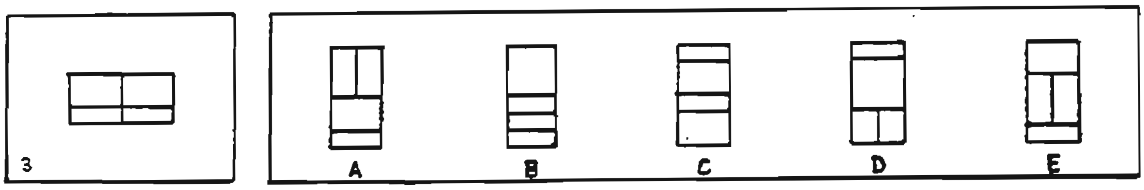
These are exercises in finding rearranged figures. Find the lettered figure which is made up of the same pieces as the numbered figure. Below is an example:

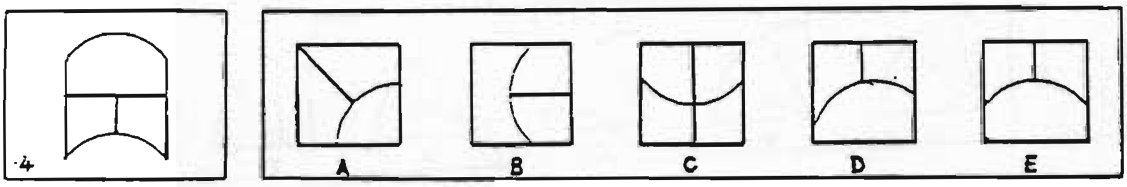


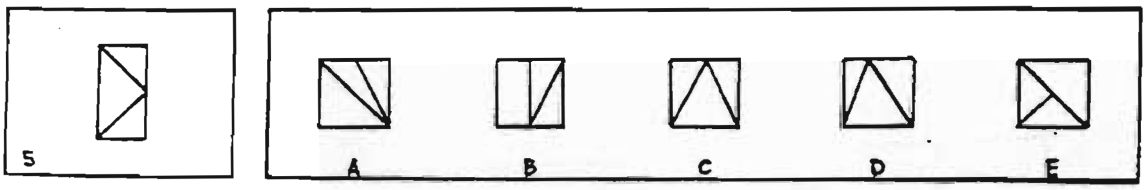
The correct answer is A since it is made up of the same pieces: 2 long pieces and one smaller piece. Therefore, cross out the letter A on the answer sheet next to question 1.

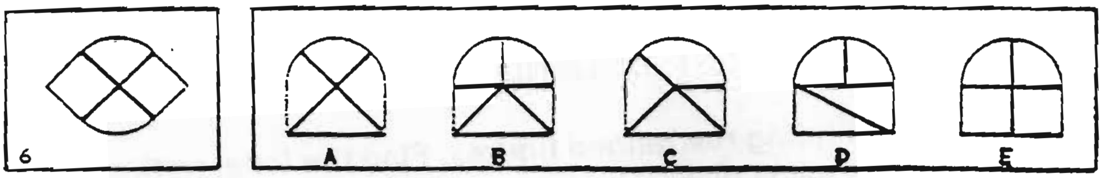
Answer the following:

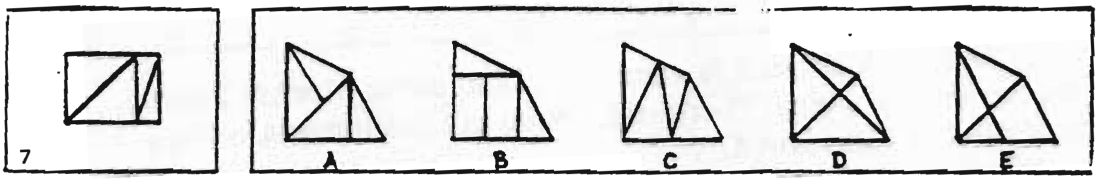


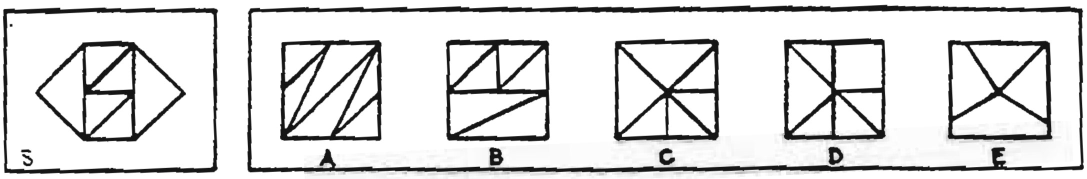


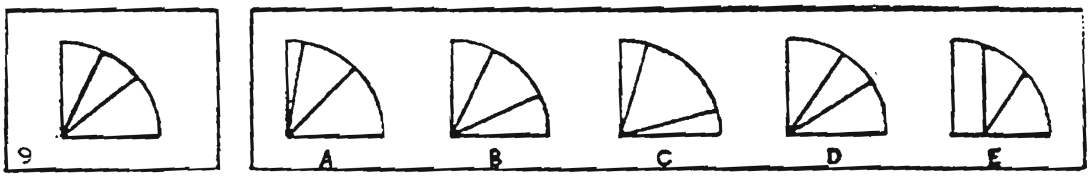


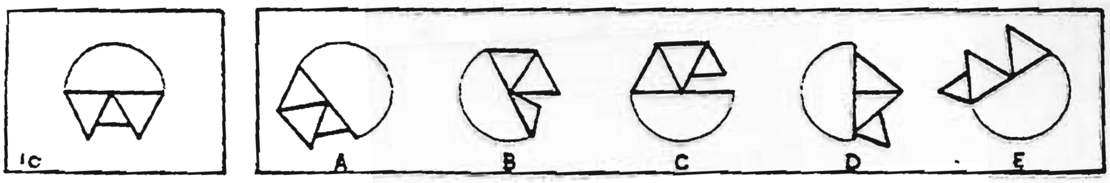



6
A
B
C
D
E


7
A
B
C
D
E


8
A
B
C
D
E

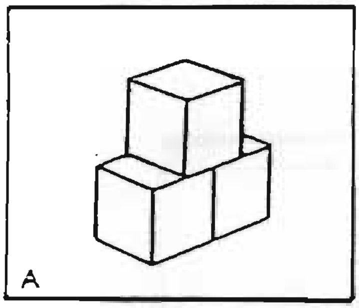

9
A
B
C
D
E

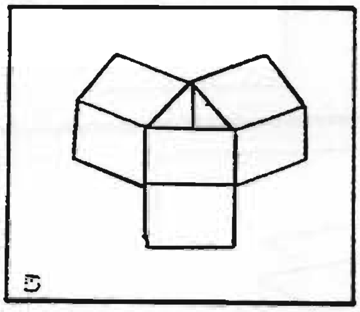

10
A
B
C
D
E

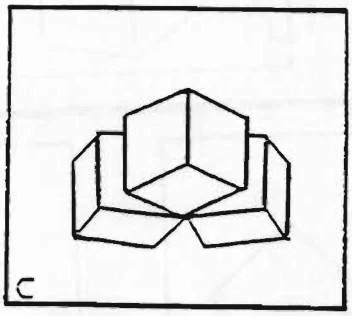
PART B
INSTRUCTIONS

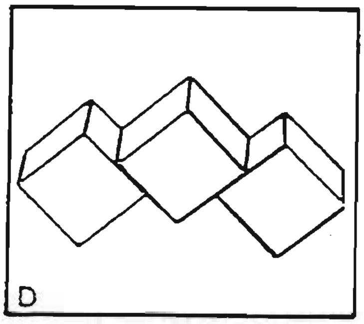
Each page of the test is divided into two by a heavy black line. Above the line there are five different sets of blocks, lettered A, B, C, D and E. Below the line are five different sets of blocks, but viewed from other angles. The drawings below the line are the test questions. Study each question carefully and decide which one of the five drawings above the line, is a drawing of the same set of blocks. There is only one correct answer for each question.

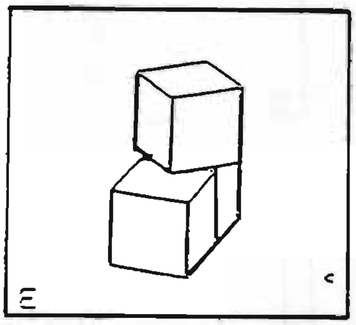
Question 11 below is an example. B is a drawing of the same set of blocks but viewed from another angle. Therefore, cross out letter B on the answer sheet next to number 11.

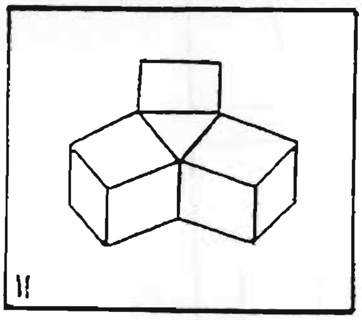


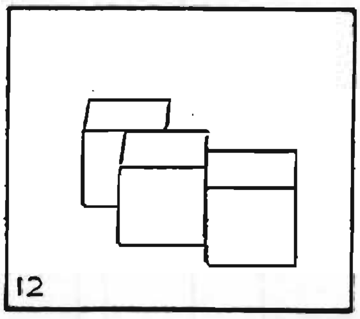


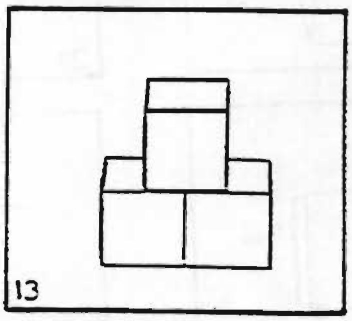


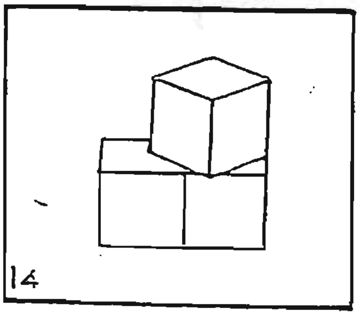


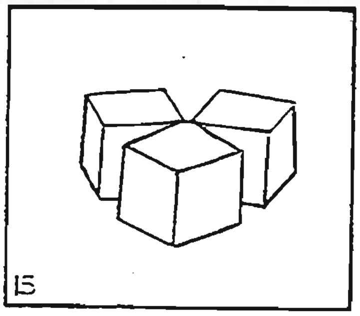


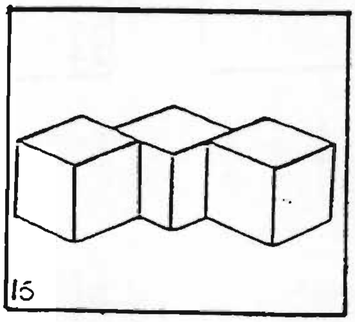


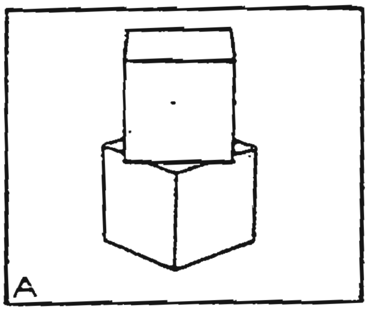








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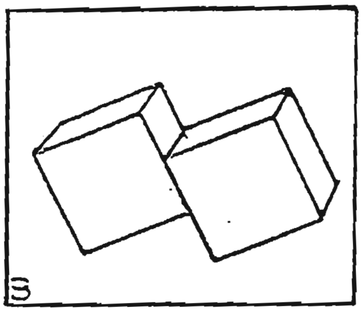
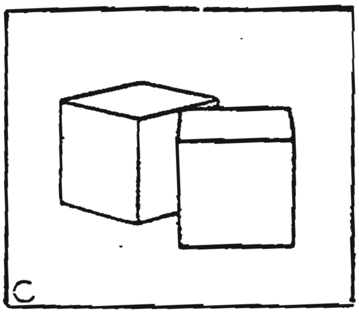
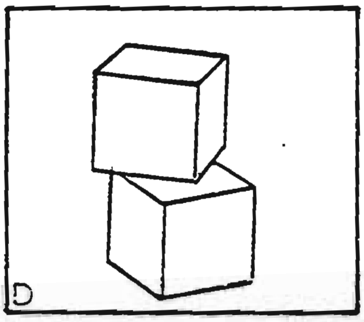

B


C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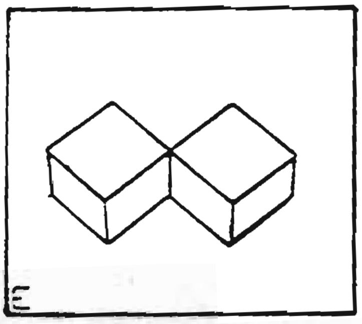
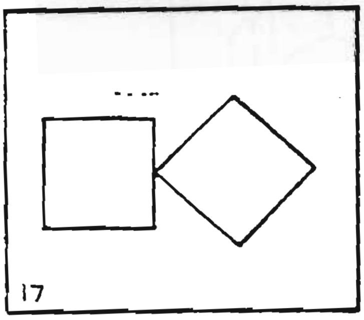

E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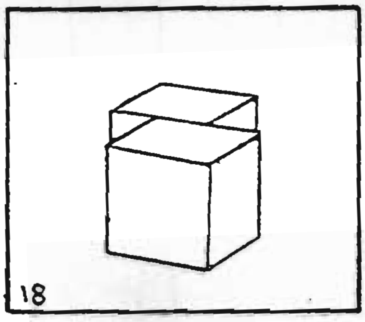
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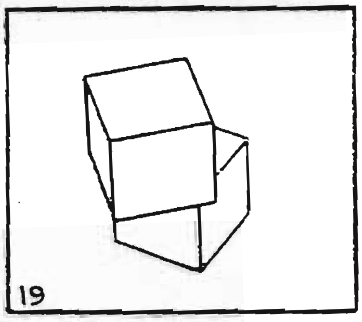
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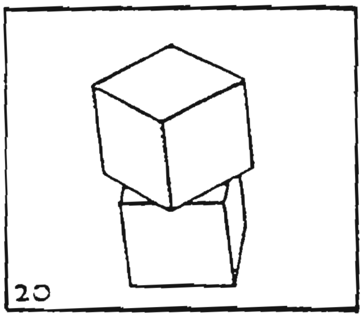
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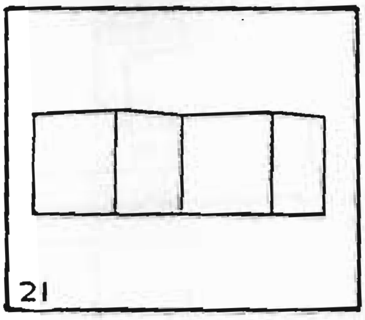
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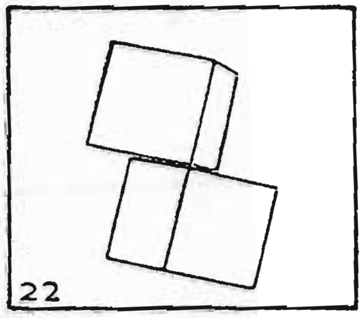
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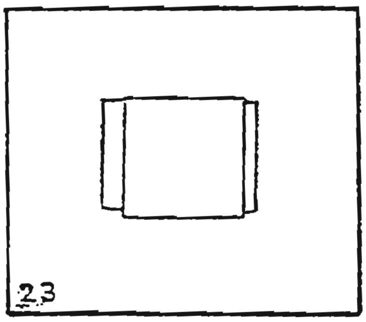
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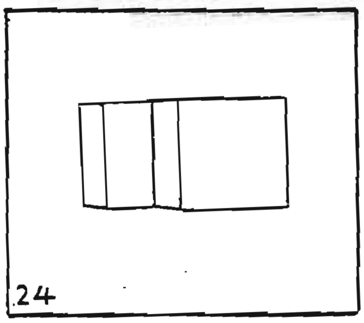
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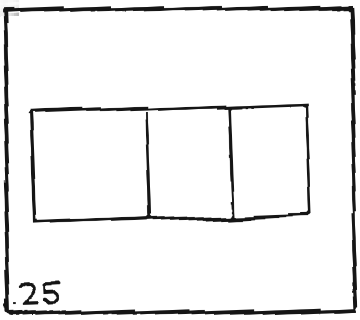
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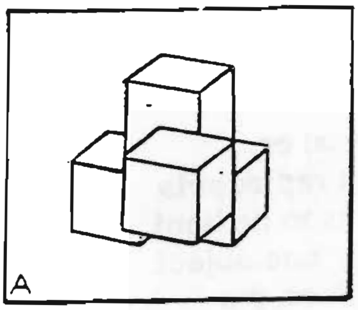
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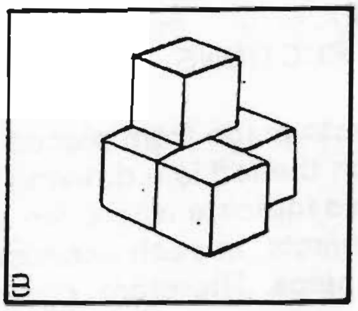
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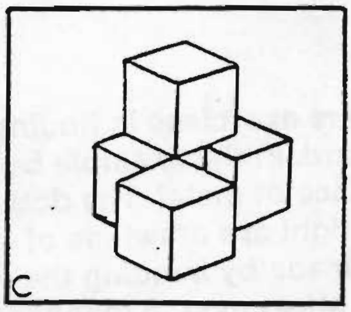
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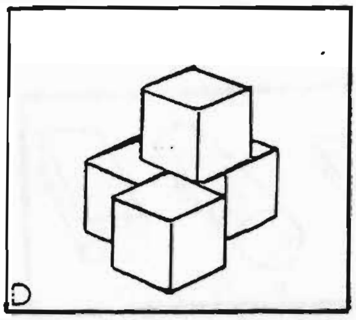
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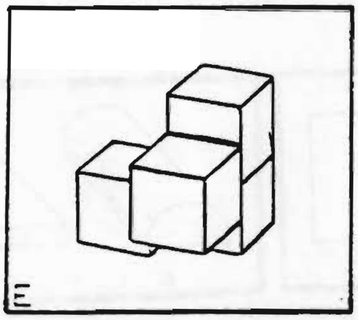
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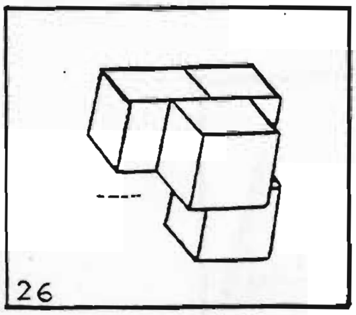
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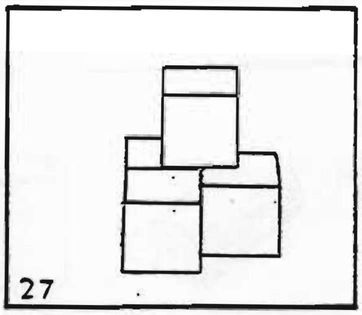
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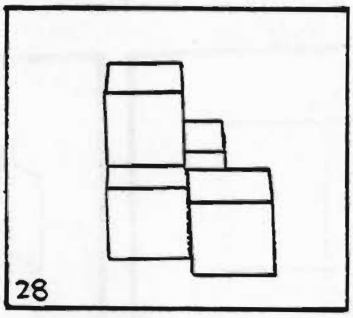
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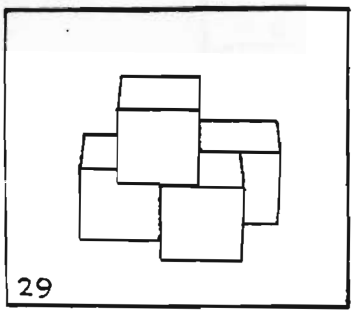
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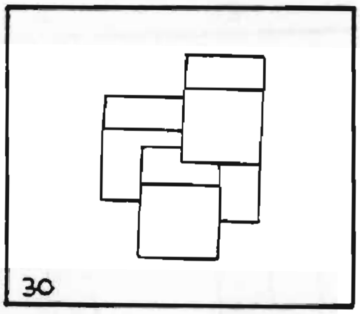
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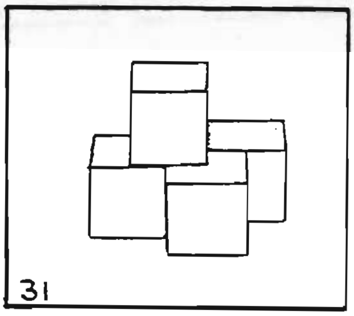
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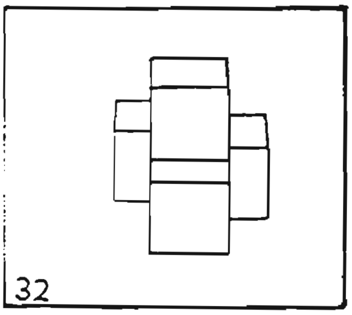
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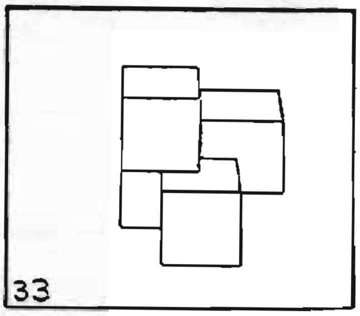
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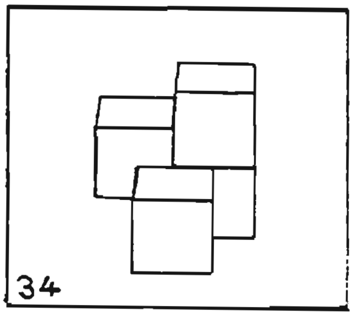
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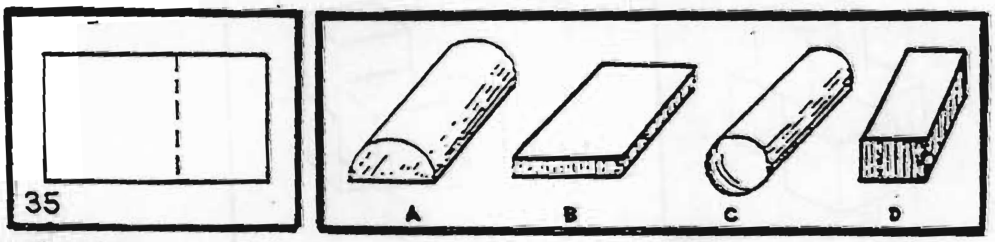
PART C
INSTRUCTIONS

These are exercises in finding objects made from pieces of metal or cardboard. In the example below, on the left is a drawing which represents a flat piece of metal. The dotted lines indicate where the metal is to be bent. On the right are drawings of four objects. In each exercise, only one object can be made by bending the metal piece. Therefore, cross out A on the answer sheet next to number 35.



Do the following: