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An Exploration Into the Educational Applications of Concept-Mapping with the Aid of Virtual Reality Technology

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ABSTRACT

This paper explores the emerging role of multimedia technology in education with respect to concept-mapping. A brief sketch is made with respect to developments in software and hardware technology with respect to education. The latest technology with potential applications to education, namely virtual reality, is viewed with respect to the role it plays in education. Thereafter, possible applications of virtual reality technology are explored with respect to concept-mapping. The paper ends with a number of conclusions and suggestions with respect to virtual reality and concept-mapping.

Introduction: Concept-Mapping and The Need For New Innovative Educational Techniques to Improve Student Achievement

With the impending approach of the twenty-first century comes a range of technological breakthroughs that have found successful applications to the educational mileau. The marriage of computers and education is already a deeply researched (and applied) phenomenon. Apart from technological tools, very interesting learning techniques such as concept-mapping have also been devised. Concept mapping shows the hierarchical relationships of concepts by graphically depicting levels of concepts (Novak & Gowin, 1984; Novak, 1990). It also shows the nature of the relationships between ideas through the use of linking words that connect the concepts (Novak & Gowin 1984; Novak 1990). Fisher (1990) notes that concept-mapping provides "healthy mental exercise" due to the mental construction effort involved in linking one idea to the other.

Despite innovative breakthroughs such as concept-mapping, the bulk of the North American educational system seems inadequate to meet the learning needs of students. For example, studies conducted with science achievement have consistently shown that students have not learned much science (Mullis & Jenkins, 1988; National Science Foundation & Department of Education, 1980). In fact, over the years, the level of science achievement has shown a downward trend (Anderson & Smith, 1986). One reason for this failure may stem from the fact that students are encouraged to learn via the "rote-learning" method as opposed to "meaningful learning". Meaningful learning is the process in which the student is actively relating new ideas to existing conceptual knowledge (Ausubel, 1968). Students develope true scientific literacy as they understand these concepts and their interrelationships, and can apply these understandings to new situations.

Concept mapping leads students away from rote-learning strategies and leads them toward the true understanding of concepts and how they relate to each other (Ault, 1985), a key factor to successfull learning, retention and recall. As Ault (1985) notes in his paper "Concept Mapping as a Study Strategy in Earth Science", each concept depends upon its relationships to many others for meaning. However, students still seem to be learning in rote-learning methods that don't emphasize the integration of concepts.

Computer-assisted learning and Concept-mapping are tools that hold great promise in helping learners learn in a manner that is meaningful and can integrate successfully to the learner's existing body of knowledge.

With the increasing quantity and complexity of information, educational tools must now be tailormade in such a way as to help the learner more fully participate and engage in his/her learning process. By taking a more active role in learning, the learner has a greater chance of staying motivated. As noted shortly before, the majority of students still engage learning in a linear "rote-learning" techniques. Information is viewed simply as a series of facts which are to be memorized, without an emphasis on the in-depth meaning of those facts or the relationship between various concepts. Novak's concept-mapping technique challenges the learner to map out the relationship between the concepts and to explain the relationship(s) between them. This not only provides the learner with the opportunity to practice meaningful learning but to have a unified "topographical" view of the information he/she is attempting to master. This author proposes the utilization of tools that help enhance that process. Since the very nature of concept-mapping is interactive in that the learner is actually participating in his/her learning, tools are needed that actually enhance the "interactive" nature of that learning process. Computer technology is already being utilized to that effect, and developements are currently underway to improve the interactive nature of learning (Fisher, 1990; Jaeggli, 1992; Knussen, Tanner, Kibby, 1991; Reisman, Carr, 1991; Friedlander, 1989). One specific area of contribution by computers in the field of education is in the area of multimedia.

Multimedia Technology and Learning

In order to appreciate the role that multimedia is playing in modern day education, one must view it in the context of individualized instruction. Since the 1950s, individualized instruction has taken the form of self paced study, programmed instruction, computer assisted instruction, computer managed instruction and multimedia instruction (Reisman, Carr, 1991). Apart from self paced study which uses printed text, all the other categories use computer technology as delivery mediums. Programmed instruction however, uses printed material as its medium, eventhough computerization is possible (Reisman, Carr, 1991). The power of programmed instruction lies in its ability to provide feedback to the learner; a feature that has been incorporated into systems such as computer assisted instruction and multimedia. Computer assisted instruction (cai) is capable of programmed instruction, contains self-study materials, is able to handle a wide range of inputs from learners, as well as using branching techniques (Reisman, Carr, 1991). Branching techniques enable the learner to simply bypass parts of the learning material which are based on the learner's responses to criterion questions. On the other hand, computer-managed instruction (cmi) extends these abilities to include testing and prescription. As Reisman and Carr (1991) point out, the problem with cmi was that instead of making the individualized instruction system more compact it became more dispersed. This lay the foundation for the birth of multimedia.

The word "multimedia" is usually confused with terms such as "hypermedia" or "interactive" media. Jaeggli (1991) defines the terms as such:

Multi: this refers to the diversity of components in a presentation, such as images, videos, text, graphics and all types of sounds.

Media: these are electronic or digital tools used in the presentation of information in the form of media such as floppy disks, videotape, videodisks and compact disk (CD-ROM) drives.

Hyper: this describes a type of access or authoring system that is non-linear in nature and provides the user with a means of arranging, combining or recombining information elements in an order that has meaning for them.

Interactive: a situation in which the learner aquires the ability to become an active participant in the learning process.

In a sense, multimedia involves the combination of textual information, still and mobile images as well as sound effects (Buckland, 1991). Knussen et al. (1991) point out that "hypermedia" appears to be of great benefit educationally by allowing the user or learner to manipulate content to a greater or lesser extent. Megarry (1988) claims that hypermedia "supports learning styles radically different from linear reading or viewing...". Amthor (1991) has found that interactive video instruction improves achievement by an average of 38 percent and reduces time to competency by 31 percent over more conventional instruction. Miller (1991) notes that interactive instruction systems such as those combining video-disk and computers are gaining widespread respectability and acceptance in the educational community.

Successful applications of multimedia technology to education already exist. One example of such an application to higher education is Friedlander's work with multimedia with the English department at Stanford university (Friedlander, 1989). Friedlander uses an interactive program called the Shakespeare Project which uses videodisk and hypercard to teach students about performance. Hypercard allows the linkage of film (such as *Hamlet* or *Romeo & Juliet*) to countless stacks of data. The student is able to choose from a large menu of topics which are programmed to unroll on the computer terminal in synchronization with the film. They can also consult dictionaries, historical notes, diagrams of stage movement or call for "help". This is all possible without having to leave the film itself. The power of this system lies in its ability to bring the visual material under the control of the learner. In concept-mapping, the learner is again empowered in a similar way by being able to manipulate semantic information. Although full fledged "multimedia-like" applications of concept-mapping have yet to impact the educational mileau, interactive computer applications using concept-mapping analogy are currently under development.

SemNet is an educational software that has incorporated many of the features of concept-mapping within itself. Computer based concept-mapping allows the learner to multiply his/her learning manyfold. In a computer based network such as *Semnet*, each concept can be linked to numerous other concepts with little concern for the crossing of lines as well as unreadable layouts (Fisher, 1990). Such a system allows for a high degree of connectivity between nodes. This interconnectivity facilitates the creation of robust representations in which each concept can be linked to many other concepts, which in fact simulates the cognitive knowledge structure of an expert more closely (Larkin & Reif, 1979).

Computer based semantic networking is made possible by a Macintosh tool called *Semnet*. Fisher (1990) notes that *Semnet* derives its theoritical basis from psychologists and artificial intelligence researchers who note that each concept is understood in terms of its relations with other concepts (Sowa, 1983). In a semantic network, each relation between two concepts is given an explicit relation name (Fisher, 1990). There is wide array of possible relations, including interactions between concept pairs that are physical, temporal, logical or hierarchical in nature. Concept names and relation names are the two basic elements used in building a semantic network (Fisher, 1990).

Fisher (1990) notes that five other programs for creating concept maps also exist:

1)*Notecards*: to assist in the management of ideas

2)*Unified Medical Language System*: for development of medical taxonomy

3)*Semnet '2'* (different from *SemNet*): to examine characteristics of large networking databases

4)*Design Journal*: to support large scale design projects

5)*Alvey/Kim Interface*: to examine issues of knowledge representation and understanding.

Apart from the above, five additional microcomputer programs for the support of the creation concept-maps also available (Fisher, 1990):

1)*Leximappe* with *Hypercard*: Analyses the co-occurrence of word pairs in text and uses the data to build concept-maps representing the text.

2)*Learning Tool*: allows students to arrange notecards (or stacks of notecards) on the computer screen and connect them with links.

3)*Inspiration*: organizes ideas from different workgroups.

4)*Pathfinder*: builds networks from semantic proximity data.

5)*The Semantic Mapper*: allows early elementary students and teachers to create concepts related to reading.

Fisher (1990) points out that Hypercard itself is not really a concept-mapping type program since the links it creates are generally unnamed and invisible, and their focus is mainly on the action produced by those links. In contrast *SemNet* and other similar semantic linking programs focus on the explicit display and labelling of links.

Overall, semantic linking programs can be contrasted along these dimensions (Fisher ,1990):
1)SemNet representations differ from typical paper and pencil concepts in that each of their relations are bi-directional.

2)Semnet is able to represent not only names but images, sound, text and formulas along with a host of other symbol systems.

3)Typical paper and pencil concept maps have the strength of being concise and well organized thereby providing a well-organized overview or *gestalt* of the information. An inherent weakness of *SemNet* type systems lie in the fact that they are relatively large and vary along multiple dimensions. These systems boast a high number of interconnected nodes resulting in the prevention of the learner from seeing any *overall pattern* to the information.

4)Semantic networks and concept-maps allow for the integration of many different ideas into a unified knowldege base. Typical concept-maps however do so within smaller topical areas.

At this stage, concept-mapping and semantic networking are both available to learners. However, a technology system may exist which may be able to incorporate the advantages of both systems (concept-mapping and semantic networking), into one medium of expression. That technology may be virtual reality.

Virtual Reality Technology and Software and its Potential Applications to the Education Realm

Once limited to the realm of science fiction, virtual reality is now on the verge of making headway into educational research (Lewis, 1991). The "learner" enters an artificial environment via three integrated mediums: (1) specially wired helmets or goggles (2)a special glove used for gesturing in the "artificial environment" and (3)eye movements. Vitual reality or VR provides a simulated three dimensional environment in which the participant feels "engaged" or enveloped. The user or "learner" is free to move about and to even manipulate simulated physical elements. Examples of this could be an architectural student "walking through" the house that he/she designed or a medical student operating on a phantom patient.

Virtual reality itself was born through the convergence of three principal technologies: computer controlled simulation for training operators of advanced aerospace and military equiptment, digital imaging and increasingly sophisticated motion picture special effects (Nugent, 1991). Watkinson (1990) describes three primary characteristics of VR:

1)*The illusion of depth* achieved by the wearing of special goggles or wired helmet.

2)*The illusion of place*. The motion of the user is tracked either from above or the floor, and the position and view in the simulated environment is changed accordingly.

3)*Interaction with the simulated environment*. This is achieved by the user wearing specially designed gloves.

The addition of virtual reality capability to present day educational tools may allow learning to be accomplished by personal experience. Kay (1991) notes that learning in adults and children is at its best when it is achieved through simulation, especially with computer software technology. The learner has a chance of actually "participating" in his/her learning process. In the case of "animal adventure", a virtual reality and educational software product from the knowledge adventure company, children can learn about animals by browsing around their habitat with the accompanying sights and sounds (Khalsa, 1993). Information about science is transmitted via full-motion videos of scientific developments, animations and simulations where the user (or learner) has the ability to control the experience. The animal adventure program introduces the learner to over 100 species of mammals, reptiles, fish, sea creatures, birds and insects. The learner can enter and move around in an animal's habitat as well as moving around the animals themselves in order to explore dimensions such as the species' habits, diet, social behaviour, etc. The science adventure program of the knowledge adventure company applies the same principle of learning to the learning of mathematics, physics, chemistry biology and a host of other science disciplines. In the science adventure program "virtual corridors" exist that branch themselves off into the various areas of science that allows the learner to explore and view various subjects at will. This is a feature that may have applications to a possible virtual reality application to concept-mapping. The program allows for interactive simulations of planetary motion, molecular motion, music, sound waves, and even a simulation that contrasts the Kelvin, Celcius and Farenheit temperature scales. A map of a plant allows the user to click on any location and view discoveries in science made in that particular location.

The above case clearly demonstrates the power of virtual reality technology in education; however its potential as a medium expressing for concept-mapping remains as yet unexplored.

Virtual Reality and Concept Mapping: A Proposal

The power of virtual reality lies in its ability to represent a fictitional three dimensional world in which objects can be manipulated by the user. Concept-mapping's strength lies in its ability to unify information, in the form of concepts, by way of semantic links. Concept-mapping provides the student with a perspective into the overall structure of the information as well as allowing the student to engage in the meaningful learning of the concepts by elaboration. The only inherent limitation lies in the fact that it can only be done in two-dimensions. Being able to extend concept-mapping into three dimensions will allow the learner more perspective and dimension for adding new concepts and elaborating on the information base. Virtual reality technology could be used to represent actual concepts in three dimensional space. The learner can also link the concepts by way of semantic links. The concept map itself can be "rotated" in three dimensions and the new concepts can be "attached" to it as the learner desires.

So far virtual reality technology seems to have found applications that are more "concrete" or "real world" in the sense that artificial environments are made to represent their counterparts in the real world (Nugent, 1991). This author proposes the use of virtual reality in order to view and build concept maps in three dimensions. As noted shortly before, concepts can now be added, however one is not limited to do so in two dimensions. As seen in previous sections, computer applications of concept-mapping known as semantic networking already exist (Fisher, 1990) however they fail to show any *overall pattern* to the information in the manner that the typical paper and pencil concept maps can. On the other hand concept-maps are limited in their potential expansion by the limited physical size of the paper they are drawn on. As the concept map grows larger, it becomes more difficult to add new concepts to it. Virtual reality technology may eliminate that liability by allowing the learner to view and manipulate his/her concept map in three dimensions. With the perception of depth in virtual relaity, the learner can "step back" and view the concept map (or maps) from a more "overall" perspective or may choose to "stand closer" and view portions of the concept map(s) more scrutiniously. The persons "glove" can be used to "move" concepts about and attach them to concept maps. Whole concept maps may also be moved and manipulated in the same way. For the writing of concepts, the learner may use a phantom (or real) keyboard. Once complete the concept maps themselves could be placed in a sort of "storage" in the same manner as disk driven computers for later recall.

Diagram #1a (see Appendix) shows a typical concept map drawn by a physics student learning the concept of fluids. Diagram #1b (see Appendix) shows the same concept-map viewed in three dimensions, presumably by virtual reality technology. Diagram #1c shows the "expansion" of the concept map via the addition of new concepts. Note how the expansion can take place in any direction in the X-Y-Z plane. Again, no matter what shape the concept map takes, one is still able to view it from three dimensions.

The Simultaneous Linking of Multiple Concept Maps in Three Dimensional Space

Thus far the possibilities of concept-mapping of individual concepts in three dimensions have been discussed. Three dimensional abstractions however open the possibility of visualizing and manipulating multiple concept maps simultaneously. Here is a situation in which the learner, in this case a physics student, is able to recall concept maps from previous lectures or readings and align them alongside his present concept map (fluids). This situation is analogous to the *Learning Tool* software program discussed earlier in which the student is allowed to arrange notecards (or stacks of notecards) on the computer screen and connect them with links.

Wether one is working with one concept map or many, each concept may find itself connected to an evolving "network" of information which will take on a unique shape. In order to enhance the qualities of that "three-dimensional" concept map, we may borrow features available in the *Semnet* semantic networking program. Concept representations may include not only text but images, sound, as well as a host of other symbol systems. Diagram 2 (see Appendix) shows the fluid concept map connecting with other concept maps. Note the analogy of the diagram to Hebb's circuit analogy (Hebb, 1949, 1966) and Rummelhart's connectionist approach (1989). In a sense, the concept-map is evolving into a sort of "architecture" that is unique and recognizable to the learner who created it. These unique pattern of connections lead to very robust three dimensional representations of individual concepts which have been linked via semantic links. As noted in the section with semantic networking software, this type of situation can rapidly lead to a situation in which the knowledge databse is resembling that of an expert (Larkin, Reif, 1979).

Conclusions and Suggestions

Virtual reality is at this time of writing a very new field and applications to concept-mapping are less known still. The potential of such a marriage has been briefly sketched in this paper, however more research and development is needed in this field. One suggestions may be to *explore the possibility of developing a virtual reality software product for concept-mapping.* As seen earlier in this paper, a relativley large number of distinguished computer companies have produced and researched in the area of semantic networking. Educational researchers interested in the area of concept-mapping may combine their efforts with semantic networking software developers alongside technologists in the virtual reality realm.

A number of advantages may arise out of the development of a "three-dimensional" concept-map:

1)Reduction in learning time: due to the three dimensional and visual nature of the information, more links and patterns become evident in this type of concept-mapping. Patterns of connections and links are highly visible in such a system, thereby reducing the time needed to "figure out" the subtle nature of those links. Since concepts and entire concept maps are now clearly visible in one medium, potential "connections" are much more evident than they otherwise would be.

2)Increased recall and retention of information: The situation in 1) may in turn lead to improved memory and learning for the information. Also, the unique "shape" of the three dimensional concept map may further add to its effectiveness for recall.

3)Increased enjoyment and motivation in learning: The very nature of such a learning system may make learning much more enjoyable than the more conventional approachews to learning. The efficacy of concept-mapping has already been proven in numerous studies (Schmid & Telaro, 1990; Jegede, Alaiyemola, Okebukola, 1990; Wallace 1990). Its marriage to the exciting field of virtual reality may hold great promise for student success in the field of education.

Unfortunately, the greatest inhibiting factor at the present time is the huge cost of virtual reality technology. Thus far, the greatest users of this field have been areas such as the the defense and aeronautics industries as well as motion picture special effects (Nugent, 1991). As costs reduce however, the possibility of applications to education may become evident. Who in the 1950's for example would have dreamed that computers would so revolutionize education in the near future?

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APPENDIX

DIAGRAM 1a

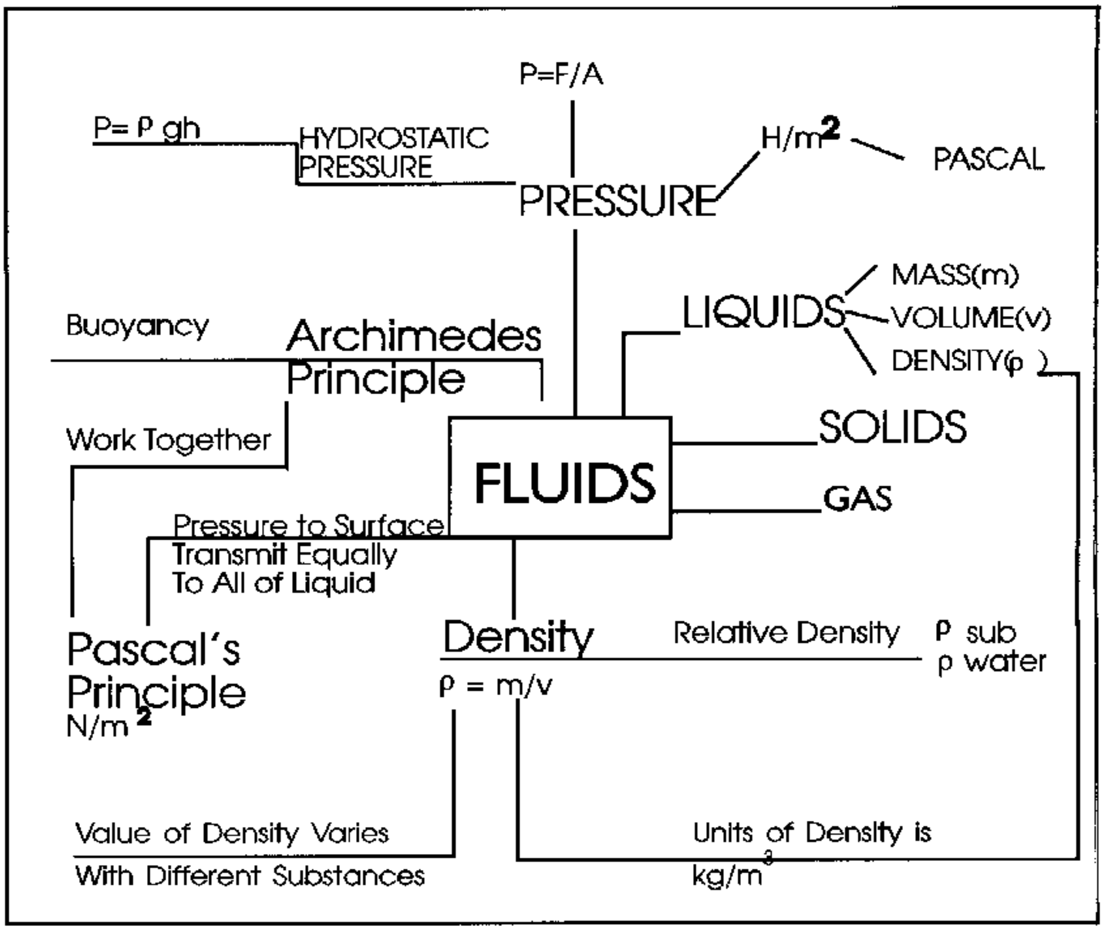
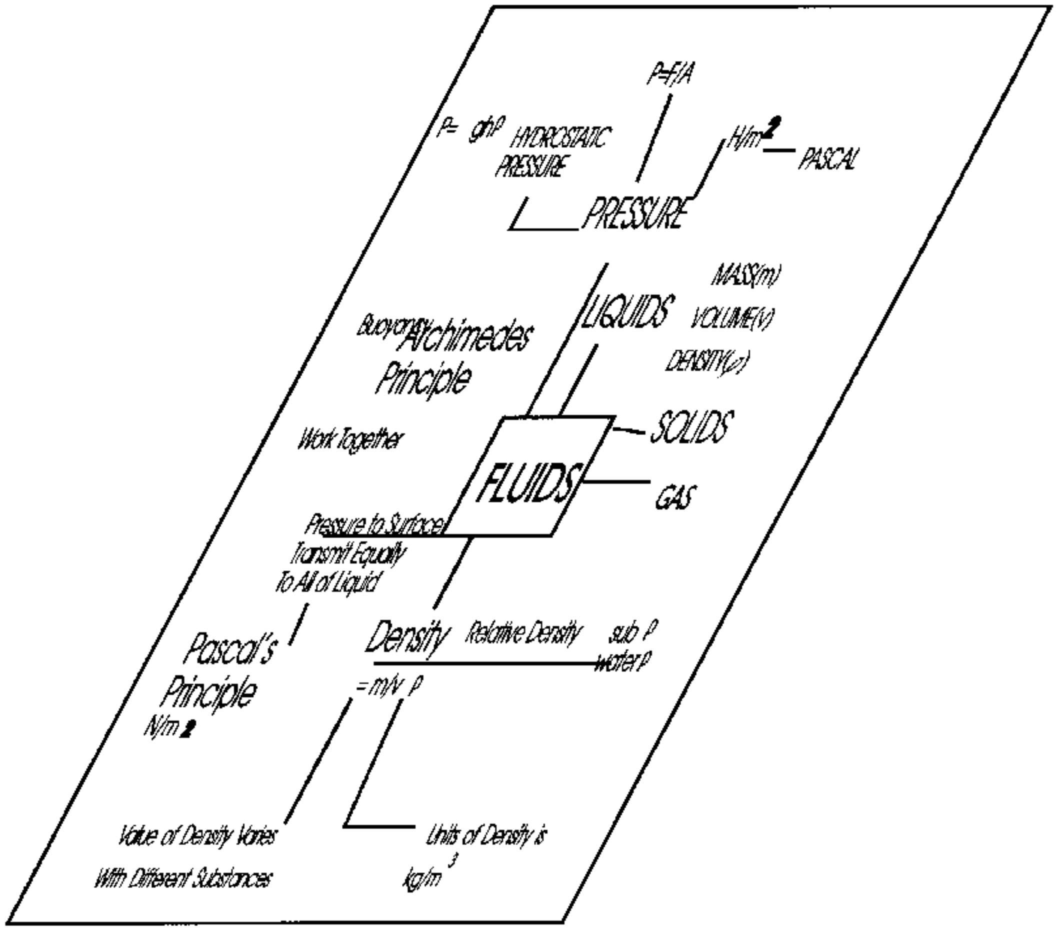
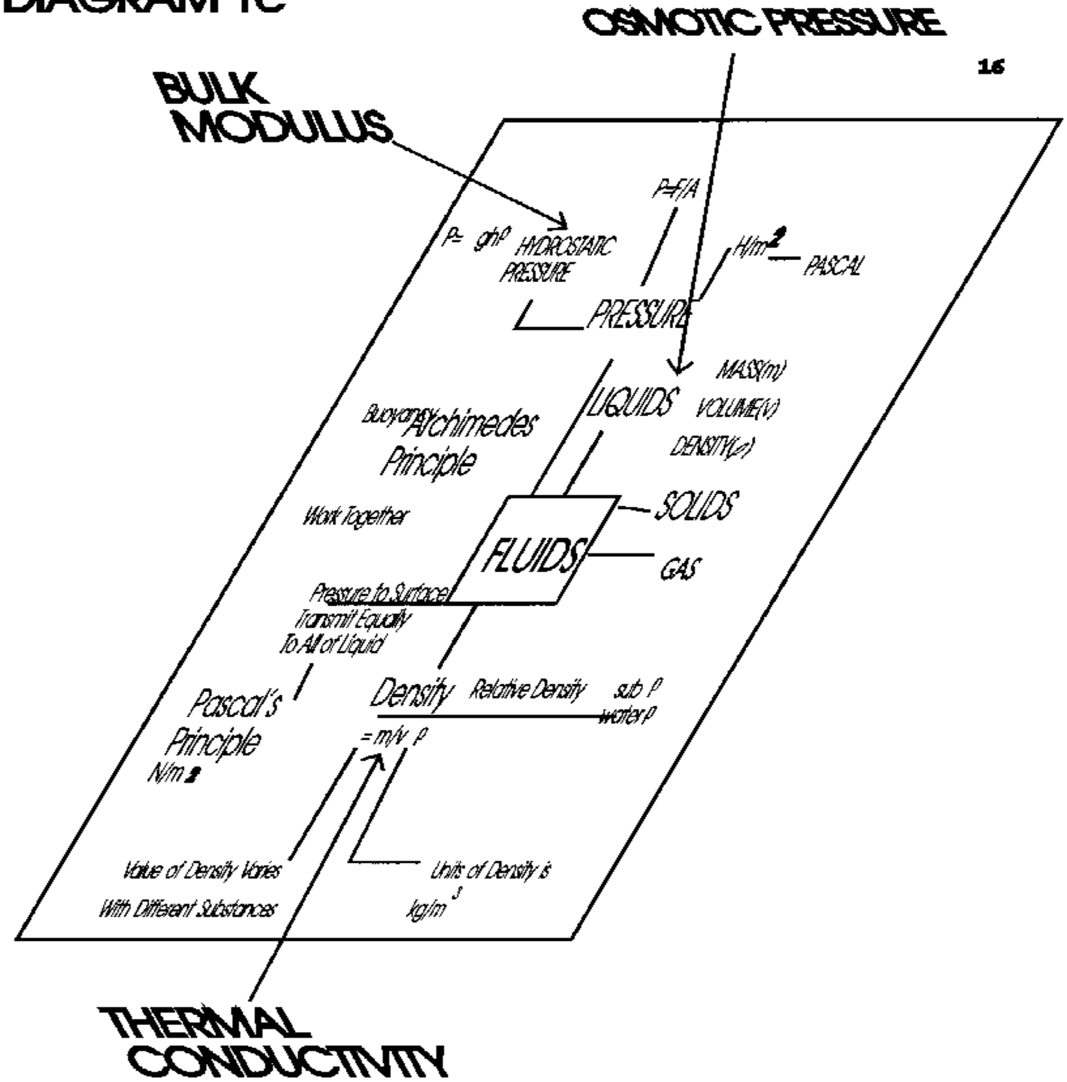


DIAGRAM 1b



P=F/A
P= ghρ HYDROSTATIC PRESSURE
N/m2 — PASCAL
PRESSURE
MASS(m)
LIQUIDS VOLUME(V)
DENSITY(ρ)
Buoyancy Archimedes Principle
Work Together
SOLIDS
FLUIDS
GAS
Pressure to Surface Transmit Equally To All of Liquid
Pascal's Principle
N/m 2
Density Relative Density sub ρ / water ρ
= m/v ρ
Value of Density Varies With Different Substances
Units of Density is kg/m3

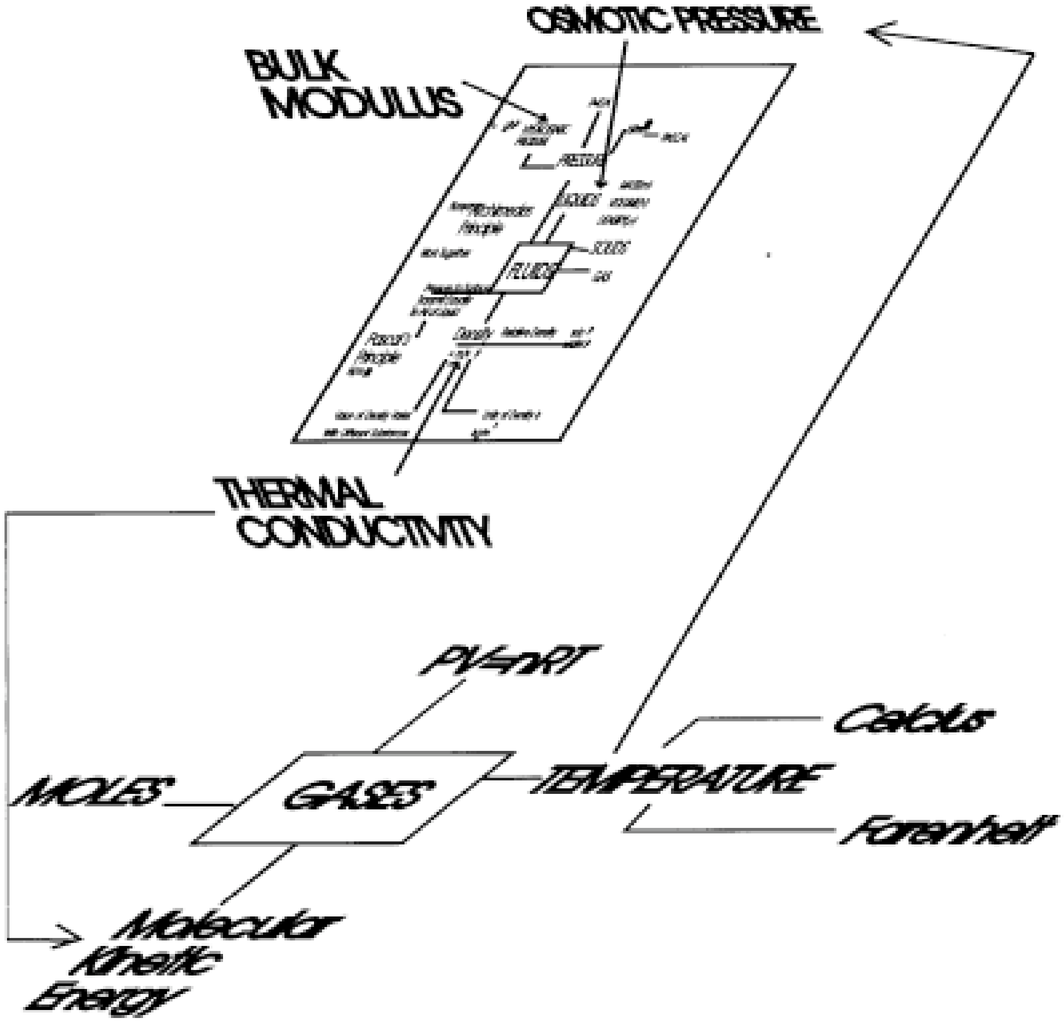
DIAGRAM 1c



OSMOTIC PRESSURE
16
BULK MODULUS
P=F/A
P= ghρ HYDROSTATIC PRESSURE
N/m2 PASCAL
PRESSURE
MASS(m)
LIQUIDS
VOLUME(V)
DENSITY(ρ)
Buoyancy Archimedes Principle
Work Together
SOLIDS
FLUIDS
GAS
Pressure to Surface
Transmit Equally
To All of Liquid
Pascal's Principle
N/m 2
Density
Relative Density
sub ρ
water ρ
= m/v ρ
Value of Density Varies
With Different Substances
Units of Density is
kg/m 3
THERMAL CONDUCTIVITY

DIAGRAM 2

17


OSMOTIC PRESSURE
BULK MODULUS
PRESSURE
LIQUIDS
Archimedes Principle
FLUIDS
SOLIDS
Pascal's Principle
Density
THERMAL CONDUCTIVITY
PV=nRT
Celcius
MOLES
GASES
TEMPERATURE
Farenheit
Molecular Kinetic Energy