A Comparison of Books and Hypermedia for Knowledge-Based Sports Coaching

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Hypertext systems are often presented as advanced alternatives to books, allowing material to be presented with its natural structure rather than forced into a linear sequential form. However, books may also be used to present highly structured material in a non-sequential form, particularly in reference works and in training manuals. While comparisons between books and hypermedia are widely made, there are very few examples of extensive material that is available in both book and hypermedia form. This paper presents a major example of a series of sports coaching handbooks and hypermedia presentations of the same material, in which the use of both media has been optimized independently and meaningful comparisons can be made.

INTRODUCTION

Hypermedia systems based on personal microcomputers coupled to videodiscs and CD-ROMs offer new opportunities for presenting instructional material in applications such as industrial training and sports coaching. The cost of the technology is now low enough to make widespread use of such systems feasible. However, the cost of preparation of the material to be presented can still be prohibitive, a problem that has undermined many developments in computer-assisted learning over the years. Recent advances in expert systems have suggested that a "knowledge-based" approach to the specification of instructional material may be very effective in managing significant system developments. This involves making the underlying conceptual structures completely overt and using these to direct the sequencing and control of instructional material. Since these structures may also be presented to the student as a "map" of the material available, freedom in the use of the material can be combined with guidance about appropriate instructional sequences.

Skills training is known to be a particularly difficult area for presentation because so much of the learning involved is non-verbal. There has been substantial progress in recent years in our understanding of the knowledge structures underlying the performance skills of athletes and the coaching skills of those involved in their selection and training. The abstract knowledge structures for sports coaching have been developed independently of specific sports (Vickers, in press b). They have been shown to lead to significant analyses of a wide range of sports that guide the generation of coaching strategies and the individual acquisition of playing skills, and to be highly meaningful and comprehensible to both coaches and players (Vickers, in press c). These knowledge structures are being applied through a variety of media.

In the research laboratory we have developed a range of hypermedia systems based on the knowledge structures (Vickers, 1987), including an expert system for ice hockey coaching (Vickers & Kingston, 1987) that was shown at the Winter Olympics in Calgary, February 1988. This runs on a Macintosh using specialist knowledge-based coaching and videodisc control software written in Pascal. Film for the videodisc has been shot during a number of international games and associated training. Figure 1 shows the system in use during the Olympic demonstrations.

It is important to note that the knowledge structures developed for expert systems are also applicable to the presentation of material in conventional media, such as books. Hence, the cost-effectiveness of hypermedia needs to be compared not with previous presentational techniques but with comparable knowledge-based approaches using conventional media. The new Steps to Success book series from Human Kinetics Publishers is based on the explicit use of knowledge structures in handbooks for athletes and coaches. Initially, ten sports are covered, including archery, badminton, basketball, golf, gymnastics, tennis, and swimming, among others.

This paper is based on our experience in developing the knowledge structures, book series, and hypermedia systems, and in comparing and contrasting the resulting delivery systems for instructional material. It summarizes the knowledge-based approach to instructional material design and illustrates this both in abstract and concrete forms. It describes the coaching material in book form and in hypermedia form, and compares the different instantiations of the knowledge and training structures.

THE KNOWLEDGE STRUCTURES APPROACH TO BOOK AND HYPERMEDIA DEVELOPMENT

The flexibility of hypermedia is often contrasted with the rigid seriality of books. However, a well-designed book is not necessarily rigid or serial in its organization, and can achieve many of those things claimed for hypermedia. Yankelovich, Meyrowitz, and van Dam (1985) have given a well-balanced survey of the relative advantages and disadvantages of books and hypermedia. The new technology does have significant advantages, but it also has disadvantages, such as

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Figure 1. Knowledge Based Coaching System for Ice Hockey Being Demonstrated during the Winter Olympics in Calgary

comparatively high cost, lack of portability, and problems in "flipping through" in a browsing mode. The comparison of hypermedia and books needs to be taken to a level of detail in which the significant differences can be analyzed. We shall argue that the technologies of books and hypermedia have many features in common and are complementary in their applications, and that a knowledge-based design approach can generate materials in both media that can complement, rather than compete with, one another.

KBCS (Knowledge-Based Coach System) is a hypermedium system designed to aid coaches in the development of their skills and those of their players and teams. It is based on research concerned with modeling the cognitive processes of athletes through monitoring their eye movements when watching the performance of other athletes (Vickers, 1986, in press a). Previous to this the knowledge structures of master coaches and teachers were developed using other techniques (Vickers, 1983)—namely, content analyses of sport-specific technical and film sources, followed by the development of hierarchies in consultation with the expert coach or teacher. The development of knowledge structures then leads to new teaching techniques based on structured knowledge acquisition. Structures have been developed for a wide range of individual sports, team sports, dance activities, and outdoor pursuits, including archery, backpacking, badminton, basketball, bowling, jazz dance, golf, gymnastics, ice hockey, racquetball, softball, swimming, tennis, and volleyball. Figure 2 shows the top level of a knowledge structure developed as a declarative schema for badminton (Vickers & Brecht, 1987).

Perceptual-motor skills are notoriously difficult domains within which to elicit underlying knowledge structures (Nisbett & Wilson, 1977; Bainbridge, 1979); most developments of expert systems have been concerned with cognitive skills such as decision-making in which the expert can verbalize the activity, although even then the experts' explanations may not fit their behaviors (Michalski & Chilausky, 1980). However, the development of *knowledge structures* for *action* has been found to be possible for many significant sports activities, and to lead to a model for instructional design that can be applied to the generation of material for both coaches and individual athletes (Vickers, 1983, in press b). This model, and the knowledge structures involved in a particular sport, applies to the development of both books and hypermedia. The following sections outline the model, exemplify the knowledge structures, and show how they are used in different media.

Knowledge-Based Instructional Design Model

Figure 3 shows the knowledge-based instructional design model (Vickers, 1983) used in the development of books and hypermedia. It has eight modules in three phases:

- The analysis phase is concerned with the knowledge structures underlying:
- the activities to be taught;

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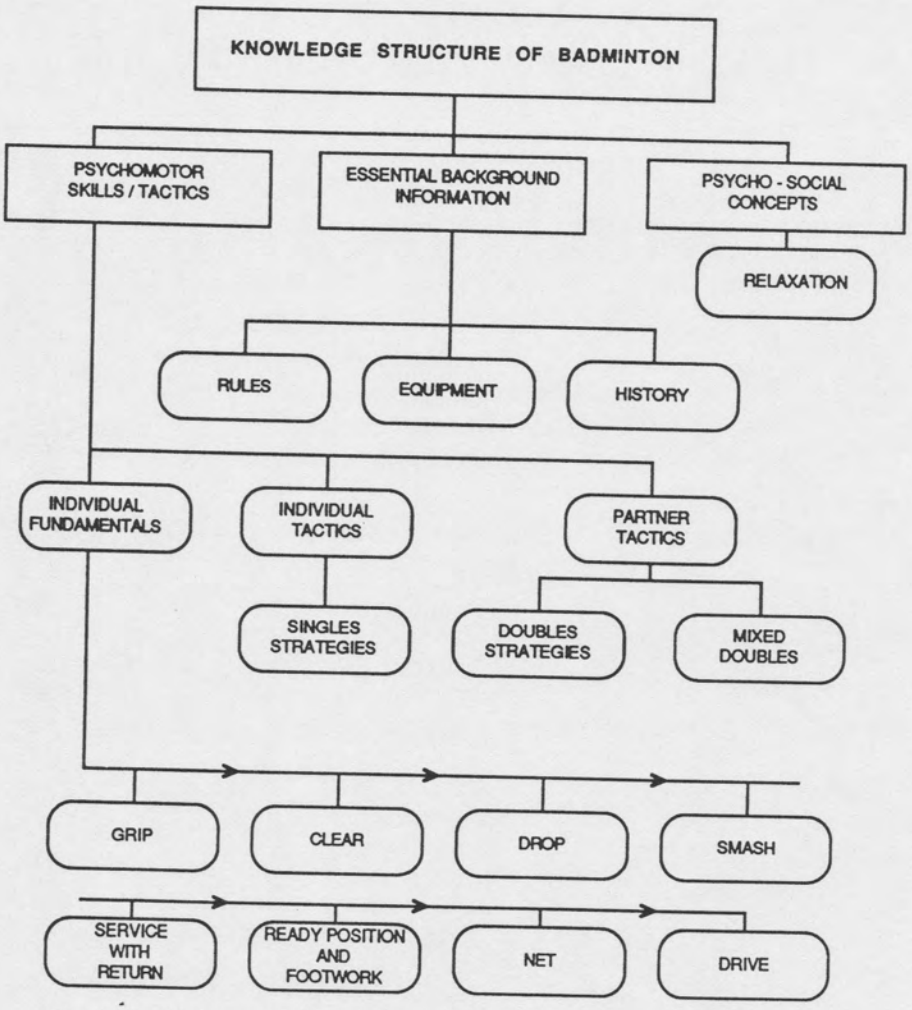

Figure 2. Top Level of Declarative Knowledge Structure for Badminton

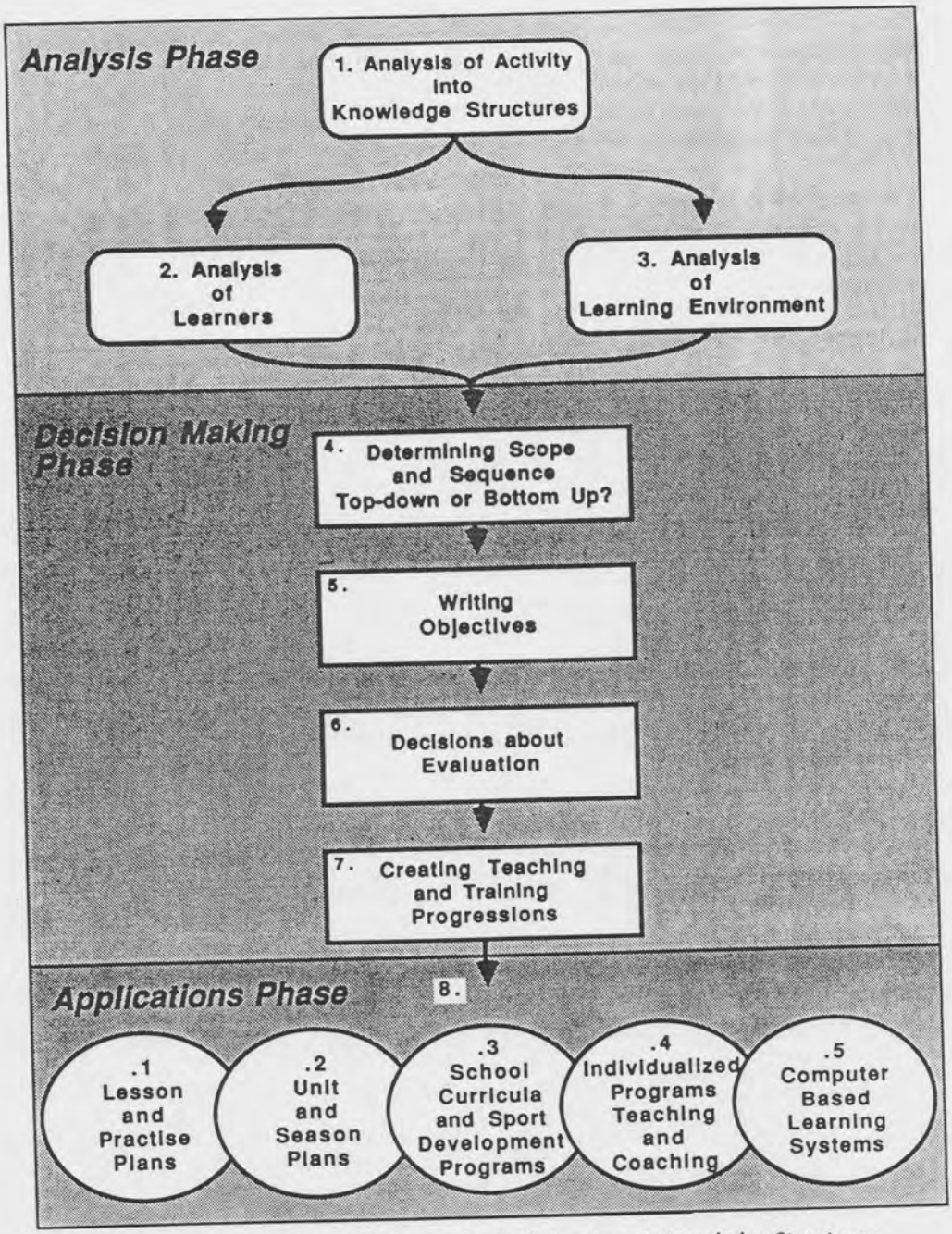

Figure 3. Instructional Design Model Utilizing Expert Knowledge Structures

- the learners;
- the learning environment.

- The decision-making phase is concerned with the use of the knowledge structures to generate actual training material involving decisions about:

- the scope and sequence of activities, particularly the use of a top-down or bottom-up approach;
- the objectives to be achieved;
- the evaluation of whether these objectives have been achieved;
- the actual teaching and training progressions.

- The applications phase is concerned with the realization of the material in a particular form for a particular purpose, such as:

- lesson and practice plans;
- unit and season plans;
- school curricular and sport development programs;
- individualized programs for teaching and coaching;
- computer-based learning systems.

The term *knowledge structure* at the top of Figure 3 originates from Glaser's (1984) work on competence models and Winograd's (1975) on declarative and procedural structures. Knowledge structures are a convenient encapsulation of information relating to a skill for purposes of communication, capturing the "cognitive economy" (Rosch, 1978) of an expert. They are best thought of like maps to a territory, useful as ways of discussing location even if the divisions are arbitrary, but even more useful if some of the divisions are contours of significant features like rivers and mountains.

A knowledge structure for action, such as that shown in Figure 2, names all the *skills* in an activity and, for each skill, their subskills. For each *subskill,* selected biomechanical, motor learning, and other technical points are represented. This information is ordered hierarchically based upon transfer of training principles, ease of learning, and the expert opinion of master teachers and coaches in the field. Also identified are *the strategies and tactics* of the activity placed in a hierarchical arrangement beginning with individual tactics and leading to partner, three plus, full game, and special situations. In addition to skills and tactics, a knowledge structure also identifies categories of *background information* for teaching or coaching such as safety, rules, equipment, history, or other areas as selected by the analyst. A third analysis centers upon the *physiological/training area* and includes warm-up, conditioning, training, and medical information. Finally, a knowledge structure can present selected *psychological/sociological concepts* such as relaxation techniques, motivation, leadership, and professional roles.

The extent to which each of these areas is emphasized determines, to an

extent, the philosophy of the resultant sport and physical education curricula. If a skills training program is desired, then the *psychomotor skills and tactics* categories will be developed more than the other areas. If demonstrated *knowledge about physical activity* is considered an important outcome, then selected concepts in the *physiological/training* and *psychological/sociological* areas will be emphasized. If an *affective* or *humanistic curriculum* is sought, then the *psychological/sociological* analyses will take precedence. A major strength of a knowledge structures approach is that the analysis can be tailored to emphasize the type of curricular content required. This strength carries over into hypermedia because the same knowledge structures and supporting material may be browsed from differing perspectives to give widely differing curricula.

Implementation of the Instructional Design in Books and Hypermedia

Knowledge-based instructional designs can be implemented very simply and naturally in book form, demonstrating that books are capable of carrying the highly structured mixture of text, hierarchical structures, and photographic material associated with hypermedia. Figure 4 shows a page from a badminton instruction book (Vickers & Brecht, 1987) showing the detailed biomechanical sequences in variants of the forehand clear in badminton. The small reproduction of the overall structure of Figure 2 at the top left places the material in context for the student. Figure 5 shows the facing page in the book containing the time lapse photograph of an expert performing the overhand forehand clear, numbered according to the knowledge structure in Figure 4. Thus the student is able to focus on a particular complete activity that forms a major component of badminton play, see it analyzed as an activity sequence, and see that sequence played out by an expert. Detailed scope and sequence tables, teaching progressions and learning activities, and performance objectives, are given based on these knowledge structures.

What does hypermedia realization of such material add to the book form? First, the knowledge structures involved, while generally far simpler than students expect, are fairly large in book form, taking up to 50 pages of detailed charts. They are daunting at first, although the serious student rapidly becomes fascinated by them. The hypergraphic presentation of the hierarchical knowledge structures on a computer screen is less daunting, and clicking on them with the mouse to access different levels is simple and natural. The computer is particularly useful in keeping track of objectives and their achievement, and presenting this dynamically in attractive graphical form. Figures 6 and 7 show screens from ActionMark (Vickers, 1987), a program using the knowledge structures to: present the skills being taught in order of presentation; describe how improvement in each skill can be attained; keep track of improvement in each skill; test on knowledge of rules, technique, tactics, and so on; provide a total score for each student at any point in time; let each student know how he or she is progressing on each skill relative to others in the class; and provide students and instructors with a variety of records and printouts.

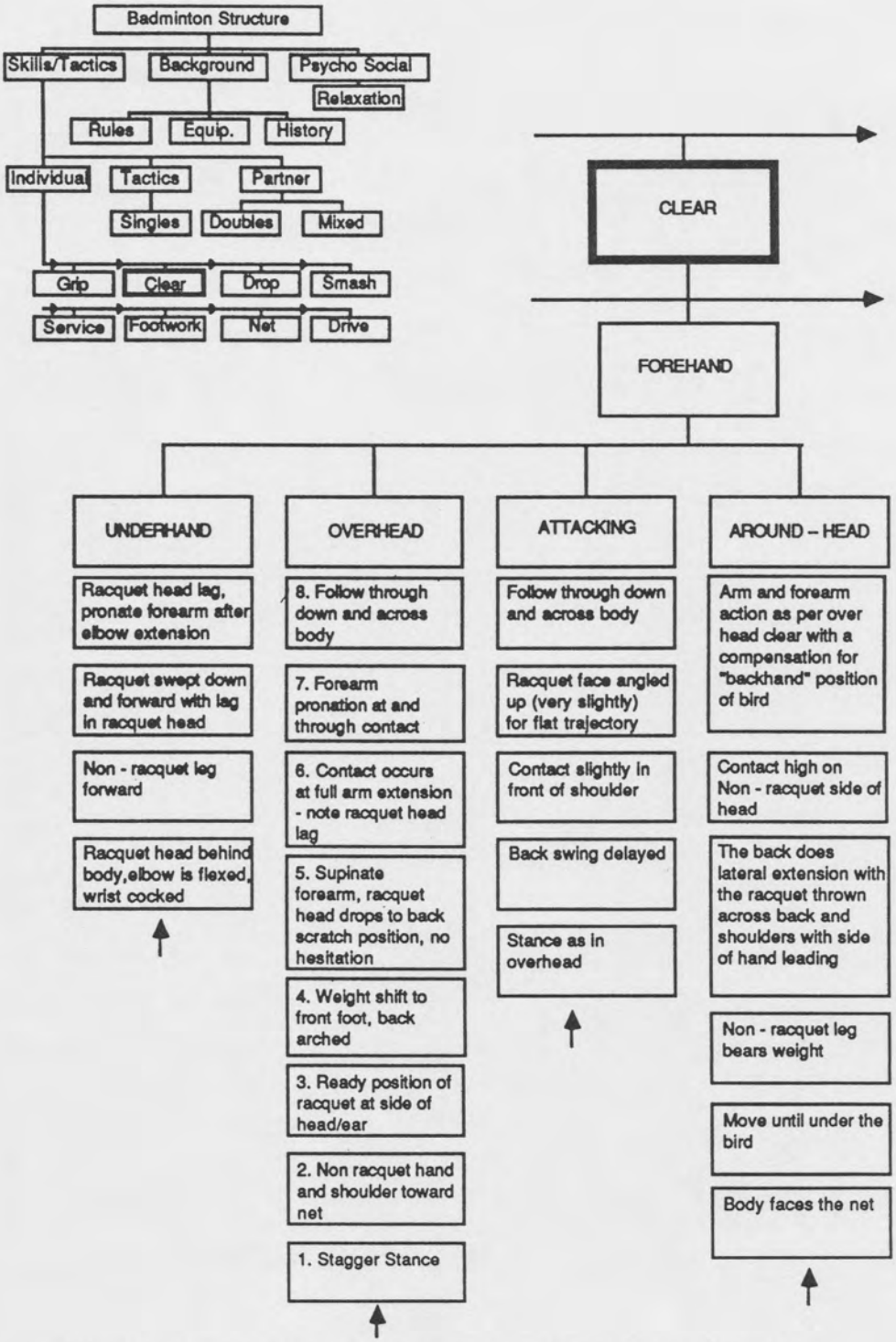

Figure 4. Knowledge Structures for Action – Forehand Clear in Badminton

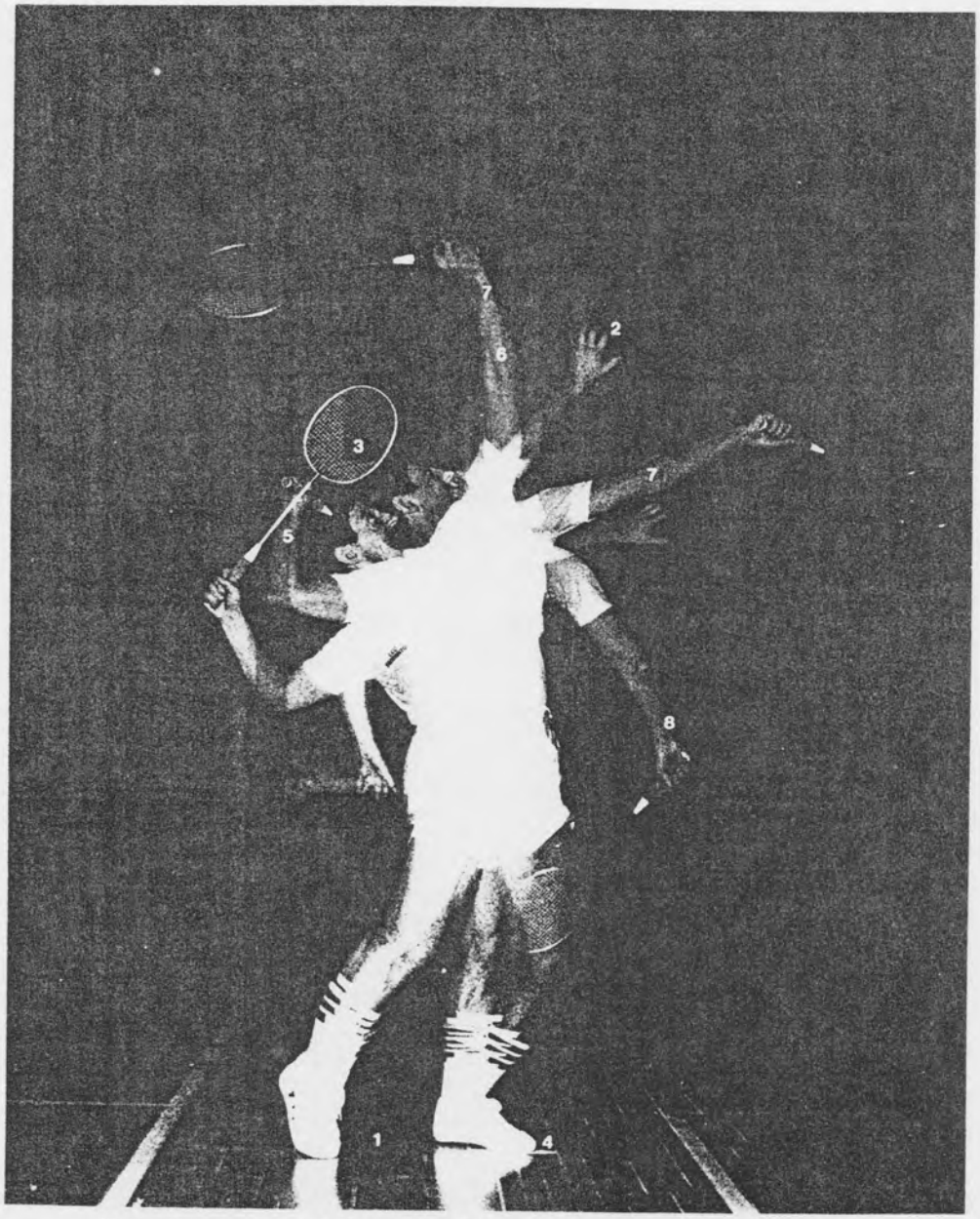

Figure 5. Associated Photograph Illustrating Action in the Forehand Clear

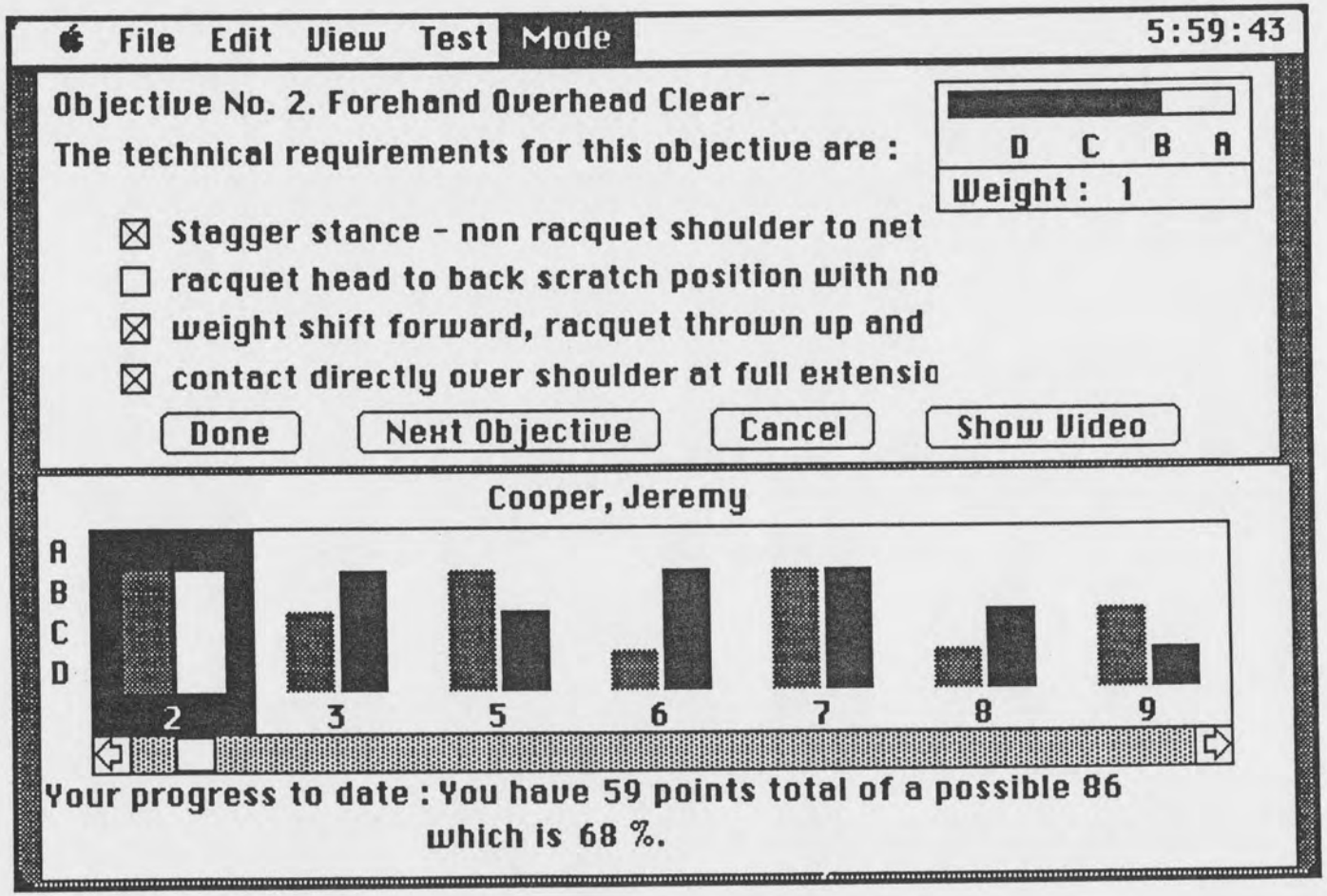

Figure 6. Action Mark Screen Showing Technical Objectives

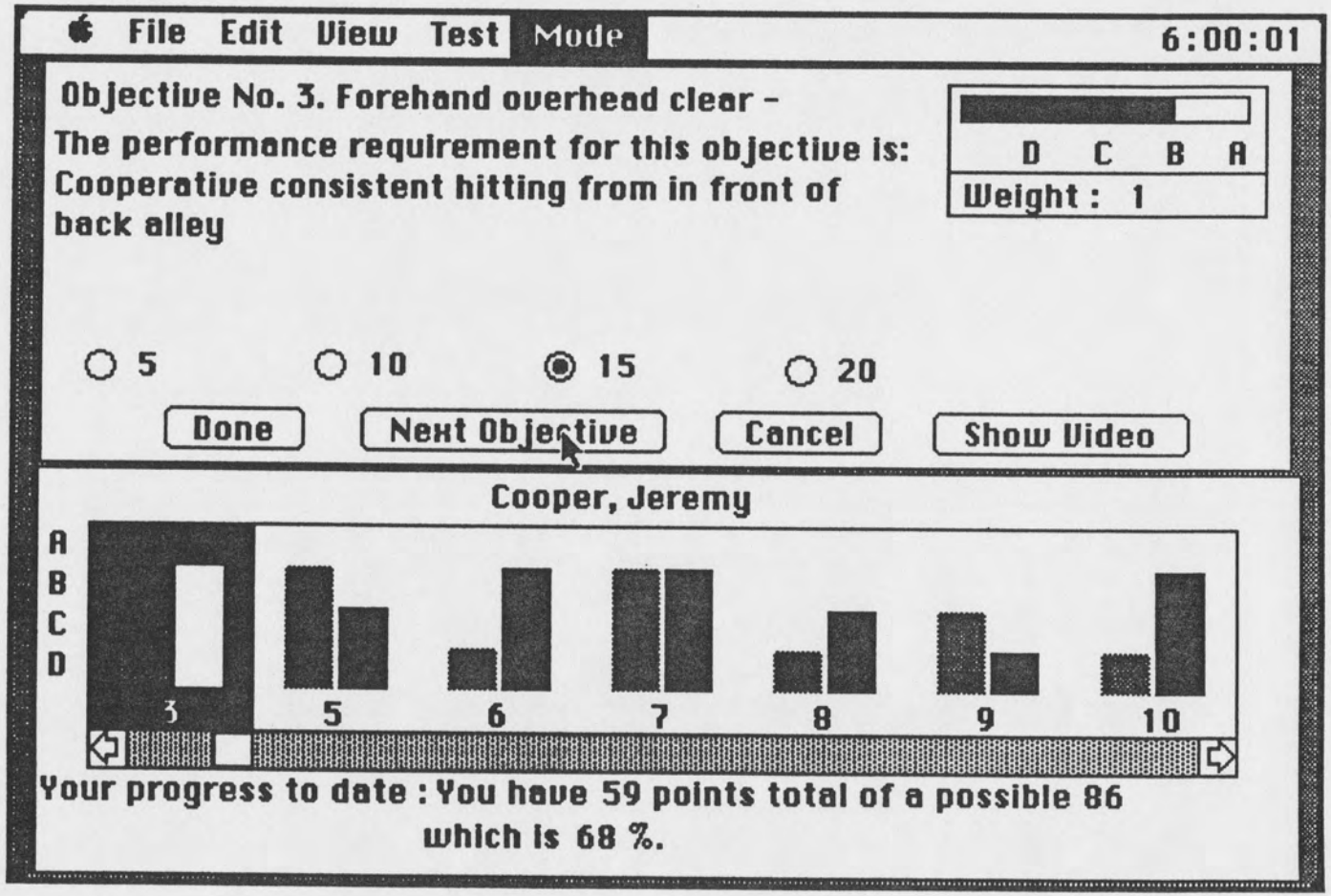

Figure 7. Action Mark Screen Showing Perfomance Objectives

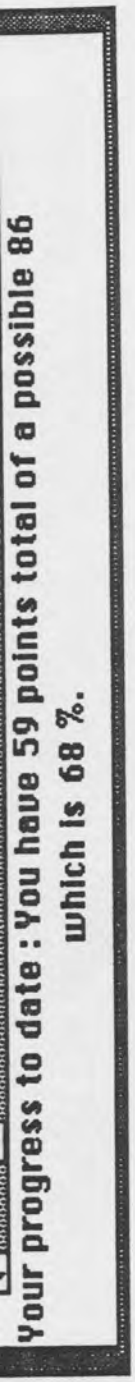

Figure 7. Action Mark Screen Showing Perfomance Objectives

The ActionView component of ActionMark gives access to a videodisc containing relevant information to each skill. It replaces the time lapse photograph of Figure 5 with a video sequence of the expert in action, allowing each stage in the biomechanical sequence to be shown stopped, and then linked into context by forwards and backwards slow and normal motion under the control of the student. This is particularly important in terms of *cognitive biomechanics,* how we cognitively understand what is observed, read, heard, or kinesthetically sensed in a physical movement. It is a term that can be applied to both performers and observers of performers, such as teachers, coaches, and judges. A person proficient in cognitive biomechanics knows the function, the purpose of the movement, and the biomechanical qualities that must be perceived in order to provide optimal feedback and assistance. For teachers and coaches, this type of information must ultimately be determined perceptually/cognitively, and is dependent upon their ability to observe a performance and judge the skill against some internal template or knowledge structure. The videodisc provides a means for transmitting this template that cannot be emulated verbally, and provides capabilities that watching athletes directly cannot. Slow motion, repetition, and overlayed graphics can provide an attention-directing analysis of key features of the activity that train the students' perception in a way that is very difficult in real time.

Implementation in hypermedia stresses the need to make many knowledge structures that are implicit in books overt so that they may be programmed for the computer. Figure 8 shows the knowledge structures and programming modules underlying KBCS, the sports coaching system. In the top layer: the *user model* and *domain model* have already been discussed; the *action model* contains coaching sequences; the *performance model* contains evaluative criteria; and the *conversation model* contains procedures for checking that material is understood. In the next layer: the *specific user* data and *advice* generation have already been discussed; the *in-system activity* keeps track of users' accesses to the hyperbase; the *out-system activity* allows actual training to be recorded; the *evaluation* data keep track of performance levels; and the *understanding* data keep track of what material has been checked as understood. The next two layers contain procedures for processing the knowledge and giving access to the hyperbase.

CONCLUSIONS

While comparisons between books and hypermedia are widely made, there are very few examples of extensive material that is available in both book and hypermedia form. This paper has presented some aspects of our experience in developing the knowledge structures, book series, and hypermedia systems, and in comparing and contrasting the resulting delivery systems for instructional material. It has summarized the knowledge-based approach to instructional material design and illustrated this both in abstract and concrete forms. It has

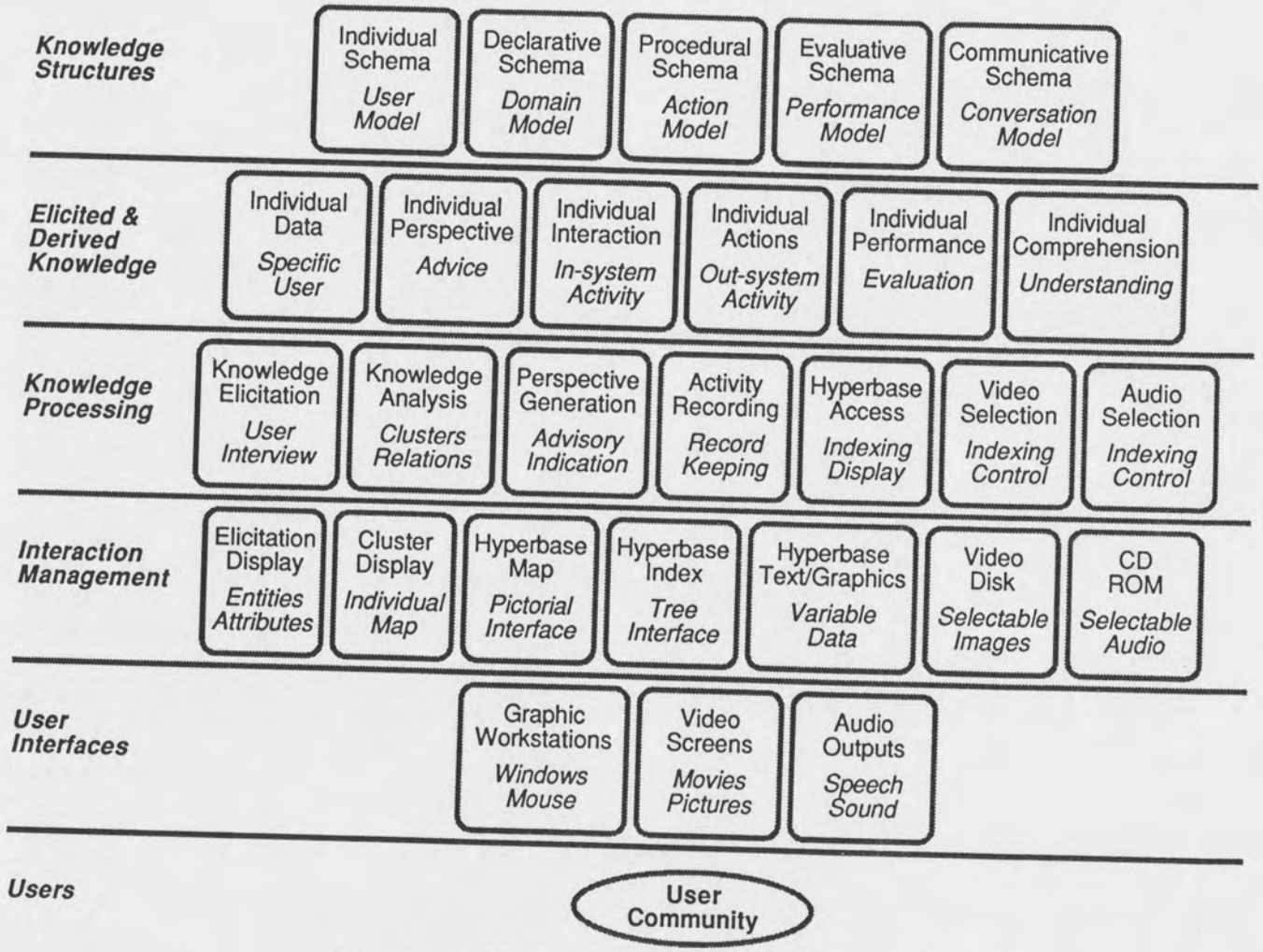

Figure 8. Architecture of a Knowledge-Based Hypermedium System

described the coaching material in book form and in hypermedia form, and compared the different instantiations of the knowledge and training structures.

Books and hypermedia are complementary, rather than competitive, technologies. Books can be used in a highly structured fashion to impart skills, but some aspects can be significantly improved through hypermedia. The combination of the low-cost, portable book as a study aid to the student, and a hypermedium system as a supportive learning environment will be the most effective approach in the short- and medium-term. It is particularly attractive to develop both systems together since the hypersystem provides a very productive development and validation environment for the knowledge structures, and desktop publishing extensions can be used to produce the book from the hyperbase.

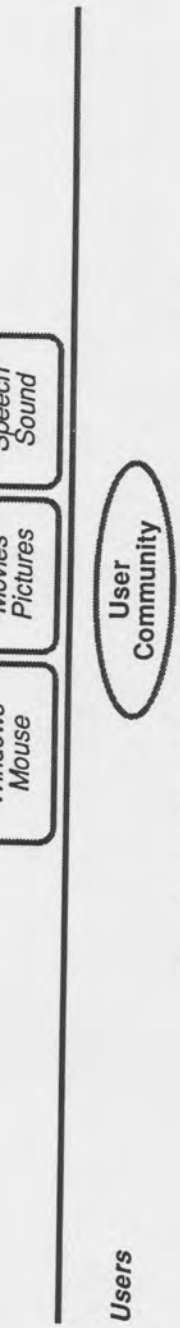

Figure 8. Architecture of a Knowledge-Based Hypermedium System

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REFERENCES

Bainbridge, L. (1979). Verbal reports as evidence of the process operator's knowledge. *International Journal of Man-Machine Studies, 11* (4), 411–436.

Glaser, R. (1984). Education and thinking: The role of knowledge. *American Psychologist, 39* (1), 93–100.

Michalski, R.S., & Chilausky, R.L. (1980). Knowledge acquisition by encoding expert rules versus computer induction from examples—A case study involving soyabean pathology. *International Journal of Man-Machine Studies, 12,* 63–87.

Nisbett, R.E., & Wilson, T.D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review, 84,* 231–259.

Rosch, E. (1978). Principles of categorization. In E. Rosch & B. Lloyd (Eds.), *Cognition and categorization.* Hillsdale, NJ: Erlbaum.

Vickers, J.N. (1983). The role of expert knowledge structures in an instructional design model for physical education. *Journal of Teaching in Physical Education, 2* (3), 17–32.

Vickers, J.N. (1986). The resequencing task: Determining expert-novice differences in the organization of a movement sequence. *Research Quarterly for Exercise and Sport, 57* (3), 260–264.

Vickers, J.N. (1987). ActionMark: A software package designed to facilitate the acquisition of complex physical skills. In D. Norrie (Ed.), *Learning in future education: Proceedings of International Conference on Computer Assisted Learning in Post-Secondary Education* (pp. 235–237). Calgary, Canada: University of Calgary.

Vickers, J.N. (in press, a). Knowledge structures of expert-novice gymnasts. *Journal of Human*

Movement Science.

Vickers, J.N. (in press, b). *Instructional design in sport and physical activity: A knowledge structures approach.* Champaign, IL: Human Kinetics.

Vickers, J.N. (in press, c). The role of knowledge in teacher preparation programs in physical education. *Quest.*

Vickers, J.N., & Brecht, D. (1987). *Badminton: A structures of knowledge approach.* Calgary, Canada: University Printing Services.

Vickers, J.N., & Kingston, G.E. (1987). Modelling the master coach: Building an expert system for coaching. In D. Norrie (Ed.), *Learning in future education: Proceedings of International Conference on Computer Assisted Learning in Post-Secondary Education* (pp. 207–212). Calgary, Canada: University of Calgary.

Winograd, T. (1975). Frame representations and the declarative/procedural controversy. In D.G. Bobrow & A. Collins (Eds.), *Representation and understanding: Studies in cognitive science* (pp. 185–210). New York: Academic.

Yankelovich, N., Meyrowitz, N., & van Dam, A. (1985). Reading and writing the electronic book. *Computer, 18* (10), 15–30.