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Pedagogy in Computer-based Sport Training

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Abstract—

The central question addressed in this paper is the appropriate formal representation of learning outcomes in the motor skill domain so they can be interpreted and manipulated by computers as well as humans for the implementation of Computer-based Sport Training (CBST). Instructional design usually begins with the specification of behavioural objectives or intended learning outcomes. The field of educational psychology has long been sensitive to the desirability of establishing learning objectives for instruction. Computer-processable learning outcomes in the motor skill domain, however, seem to have remained the silent partner of learning outcomes in both the cognitive and affective domains. This paper presents a conceptual model of learning outcomes in the motor skill domain for the implementation of CBST. The heart of this model is to treat athlete's skill as a contextualized space of capability either actual or potential. Rowing is the sport chosen as the study domain.

Keywords-intended learning outcomes; motor skill domain.

I. INTRODUCTION

E-learning should be pedagogically driven rather than technology driven. Learning outcomes, defining what is to be taught and therefore what is to be assessed. Thus, learning outcomes provide the pedagogical foundation for successful e-learning implementations.

A coach helps athletes to enhance their skills by determining the intended outcomes for their training [1]. The coach determines the instructional materials and the procedures to be used in coaching activities to attain particular learning outcomes. The procedures usually incorporate conditions for demonstrating skill, providing practice with feedback, and providing athletes with guidance for a given type of learning outcome. Behavioural educationalists call these examples rules and practice with feedback.

Planned, coordinated, and progressive coaching is needed for an athlete to successfully achieve their intended outcomes [2]. Systematic coaching activities derive from a behaviourist perspective and focus particularly on task analysis. Task analysis in the motor skills domain provides a breakdown of complex skills by detailing the muscles, nerves, and tendons involved in a given motion to identify accurate techniques and tactics congruent with the learning outcomes [3]. Such analysis generates precise and usually effective instruction that allows the coach to facilitate the coaching activities pertaining to the athletes' achievement of their intended learning outcomes, and thus allows the athletes to progressively develop their skill in an effective and efficient way [3].

Systematic planning in sport training allows congruity between techniques and tactics in achieving intended learning outcomes (ILOs), supports their assessment, and supports the instructional or coaching activities used to foster their achievement.

II. COMPUTER-BASED SPORT TRAINING

Computer-based sport training (CBST) such as video analysis, virtual reality, and ergometers provides innovative support to coaches and athletes towards the achievement of ILOs.

Video analysis of athlete action is one of the tools for analysing performance, resulting in statistics on tactics, computer-aided coaching, and performance improvements [4]. Performances are recorded on video tape and then edited to create a series of clips for subsequent screening [5]. However, coaches and athletes perceive the delay between performance and video analysis as detrimental to the effectiveness of this performance analysis [6].

Virtual Reality (VR)-based training systems [7] are oriented towards learning a sequence of discrete reactive tasks. Training occurs simply by immersing the user in a virtual environment with various scenarios, which would otherwise be difficult to experience in the real world. The given task is usually to perform a sequence of actions, in reaction to events. Importance is attached to whether the trainee has selected the right type of action, rather than how it has been done kinaesthetically [8].

An ergometer [9] is used to analyse the relationship between technique and performance. The system provides data for real-time feedback that enhances the results from learning/relearning of a motor task [10]. Biomechanical analysis in rowing involves the consideration of the kinematics and kinetics of the *boat-rower* system. The Concept II rowing ergometer [11] integrates appropriate hardware and software to quantify and graphically display information about the rower's joint kinematics and pulling force. The on-water rowing instrumentation system [12] has been designed to provide kinematic and kinetic information that has an influence on boat speed.

These examples support coaching activities by providing a learn-by-doing computerised environment in which athletes pursue ILOs by practising target skills and using instructional materials to help them achieve their learning outcomes [13].

III. PEDAGOGY

Pedagogical principles are theories that govern the good practice of teaching and learning. Pedagogy can be defined as the 'art and science of teaching' [14] or as the 'design and development of teaching and learning' [15]. In this section, learning theories are first discussed followed by instructional design.

A. Learning Theories

Learning theories provide the conceptual underpinnings for pedagogy. A learning theory specifies the link between what is learned and the conditions under which learning occurs [16]. Mayer [17] has shown three views of learning: as response strengthening, as knowledge acquisition, and as knowledge construction.

Learning as response strengthening is also known as behaviourism, focusing on behavioural changes as a result of learning. Learners' behaviour is changed through reinforcement and feedback [18]. From a behaviourist perspective, to change behaviour one must determine what behaviour is to be changed and what the change is [16]. Thus behaviourism theory seeks to strengthen the learners' desired behaviour through positive or negative reinforcement.

Learning as knowledge acquisition is known as cognitive theory and assumes that the learners' mental processes are the major factors in learning [19]. Cognitive theory emphasises the ways in which the learners' cognitive processing and application of information change their thoughts and internal mental structures, and is concerned with learners' predisposition to learning.

Constructivist theory views learning as knowledge construction and considers knowledge as individually constructed by learners, based on their interpretations of experiences in the world [20]. The most prevalent forms of constructivist theory are co-constructivism [21] and socio-constructivism [22]. Co-constructivism can be viewed as "what we know arises in a relationship between the knower and the known" [23], while socio-constructivism can be seen as "personal constructs being developed in a social context" [24]. Thus, both co-constructivism and socio-constructivism emphasize that dialogue is an essential part of learning. Learners learn and develop themselves through a social and collaborative process using language. Constructivist theory focuses on self-regulated learning as learners determine their learning activities via their personal experiences.

Meta-theories, such as cybernetics and general system theory, attempt to look for patterns and phenomena in the natural world [25]. They provide a view from outside the educational system and look for similarities and differences that affect all systems. Cybernetic theory emphasizes the interaction between learner and learning in which the learners participate in the learning activities and learning attempts to acquire, evaluate, modify, translate, use, generate, transmit, and export information to achieve their purposes.

Learning theories are useful for understanding why an instructional design works by explicitly addressing which features of the learning environment promote intentional learning and how they may be developed.

B. Instructional Design

Instructional design presents a framework that can support the design and development of teaching and learning activities. The principles of instructional design are grounded in learning theories and offer systematic planning of instruction [26]. Instruction is planned as a sequence of teaching and learning activities targeted at the achievement of ILOs.

The field of educational psychology has long been sensitive to the desirability of establishing learning objectives for instruction [27]. These learning objectives are variously called behavioural objectives, instructional objectives, educational objectives, performance objectives, or ILOs. ILOs guide the learner and guide the teacher. The rationale is that learners will use ILOs to identify the skills and knowledge they must master, while teachers will use ILOs to guide the creation of a learning environment that supports the learning activities likely to lead to their achievement [28]. Instructional design is the design of teaching and learning activities in service of ILOs.

The instructional design process includes the core elements of analysis, design, development, implementation, and evaluation to ensure congruence among ILOs, strategies, evaluation, and the effectiveness of instruction. A wide variety of instructional design processes have been created [e.g. 29, 30, 31].

Although a variety of instructional design model have been designed, all models involve the specification of ILOs. This shows that the ILO is the key aspect that is applicable to teaching and learning situations.

1) Learning Outcomes

Instructional designers and other educators usually identify behaviourism as the source of the practice of writing explicit ILOs. Learning outcome conceptions of instructional design include the analysis, representation, and re-sequencing of content and tasks, in order to make their learning more predictable and reliable.

A machine-processable representation of the teaching and learning situation can be based on ILOs, as illustrated in Section IV.

Behaviourism and cognitivism both support the practice of analysing a task and breaking it down into manageable chunks, establishing ILOs, and measuring performance based on those outcomes [20, 32]. Cognitive science has broadened the scope of task analysis to include an analysis of the content itself. Such an analysis aims at determining the relationship between, and relative importance of, individual concepts within a subject matter domain.

The most widely investigated kind of content structure is a structure or hierarchy which shows pre-requisite relations among the components of the subject matter of a particular domain [33, 34]. The structure describes what must be known (if an ILO structure, what the learner must be able to do) before something else can be learned. A pre-requisite relation is identified by the following sentence: "A learner must know (be able to do) 'X' in order to learn (be able to do) 'Y'."

Advocates of the constructivist model of instructional design take issue with the pre-definition of ILOs. Their position is that learning outcomes can only partially represent what we know, and therefore expressing them as the exclusive content of instruction might constrain what the learner will learn and seek to learn. In constructivist learning environments, the learner is often a participant in determining ILOs and directions for learning, which can be a somewhat fluid process.

The cybernetic model encourages the setting of ILOs, and it provides a way to know when the ILOs have been met [26]. Based on the cybernetic model, the an instructional design relies on constant systemic feedback. Such an instructional system acts somewhat like a thermostat, monitoring its own effectiveness and making revisions as needed to achieve ILOs [35].

To summarise, ILOs are designed and developed in small manageable chunks. These chunks are assembled and aggregated in structured networks or hierarchies providing a systematic way of labelling and organising teaching and learning activities.

2) Classification of Learning Outcomes

Bloom and colleagues [36] have identified three domains relevant to ILOs. These are the cognitive domain, affective domain, and motor skill (psychomotor) domain.

The cognitive domain deals with the development of understanding and intellectual abilities. Bloom and colleagues [36] developed a taxonomy of intellectual capability comprising recall, comprehension, application, analysis, synthesis, and evaluation, all of which are involved in problem-solving. Their work has provided a common language for educators and has become the standard for identifying and classifying ILOs and learning activities.

The affective domain is concerned with attitudes, values, and emotions. Krathwohl, Bloom, and Masia [37] developed a taxonomy that follows a sequence from attending to phenomena, responding to them, learning to value them, organizing one's values in relation to each other, and finally creating a generalised personal value system to guide one's life.

The motor skill domain is concerned with the general area of muscle development and coordination [34, 38], and several taxonomies exist in the literature [39-41]. Three of these are presented in Figure 1. In general, psychomotor taxonomies describe a progression from simple observation to mastery of physical skills.

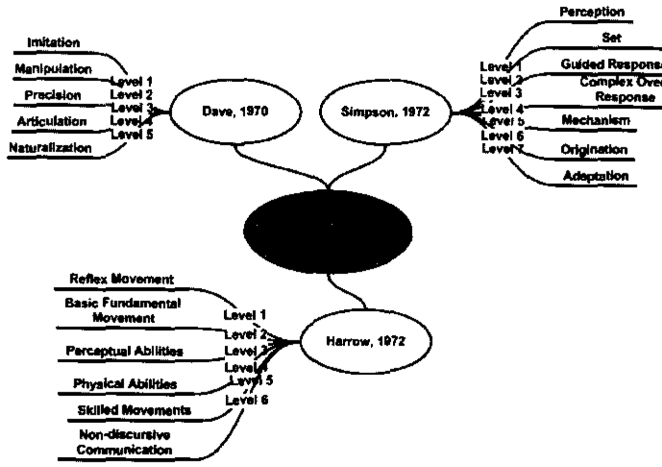

Figure 1. Categorization of learning outcomes in the motor skill domain

Although no taxonomy is universally accepted for the motor skill domain, Dave's taxonomy [28], based on the degree of coordination that is applicable to many motor skill applications, is adopted in this paper.

C. Instructional Design in the Motor Skill Domain

The analysis and training of motor skills seems to be somewhat divorced from the mainstream of educational research and development [42-44]. Bloom and his research team [45] did not complete detailed work in the motor skill domain as they claimed lack of experience in teaching these skills.

Motor skills can be conceptualised as components of procedures, involving choices between alternative movements, sequences of movements, and iterations of sequences. A motor skill procedure, which has been called the 'executive subroutine' [46], has the character of a rule by which the learner knows 'what comes after what' [34]. Motor skills can usually be divided into a series of steps or separate skills that constitute the total performance, either occurring simultaneously or in a temporal order. Learning to integrate skills that were previously learned separately has been recognised by researchers and coaching practitioners as a highly significant aspect of motor skill learning. The detail in a task analysis determines the specific muscle coordination required in a physical activity and then states the appropriate training requirements as learning outcomes.

Mastery learning and a personalised system for instruction were instructional design techniques that seemed to have a direct value and easy application for teaching motor skills [47]. Mastery learning [48] is based on the premise that learners must acquire skills in incremental, sequential progression, with pre-requisite skills being learned (mastered) prior to attempting more difficult and complex tasks. In such an approach, time is allowed to vary. That is, teachers do not hold the amount of content stable, but allow individual learners their own needed time to acquire skills. Keller developed his Personalized System for Instruction [47] at the same time. It is based on mastery learning principles in that learners progress through a syllabus only after acquiring pre-requisite skills.

Thus, ILOs in the motor skill domain should be based on the premise that learners must acquire skills in an incremental, sequential progression, with prerequisite skills being learned (mastered) prior to attempting more difficult and complex tasks. A more detailed analysis of such ILOs is provided in the next section.

IV. PROPOSED ILOS IN CBST

The design of CBST ILOs may be based on a competency model [refer 49]. The proposed ILOs describe a capability, and the subject matter to which that capability applies (Figure 2). These descriptions represent what the learner is able to do and how the achievement is capable of verification when learning has been accomplished.

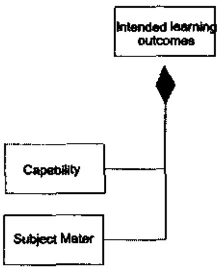

Figure 2. : Learning outcomes conceptual model

This paper adopts Dave's taxonomy to represent the components that describe different motor skill processing modes, characterised with specific action verbs [refer 50].

To develop a component of subject matter for an ILO in the motor skill domain, a learning task must be broken down into specific measurable tasks. In teaching any new behavior, a closer approximation to the goal should not be reinforced until the previous one has been firmly established. If too large a gap between previously learned skills and currently expected skills is presented to the learner, their behaviour may fail and training may have to resume at the point where the learner has repeatedly demonstrated success.

An example of a rowing procedure task analysis is depicted in Figure 3. Rowing is a periodic movement comprising the catch, drive, finish, and recovery [51]. The catch procedure is composed of parallel sub-procedures of gripping handles, positioning elbows extended, and positioning shins vertical. Positioning elbows extended will result in positioning arms extended.

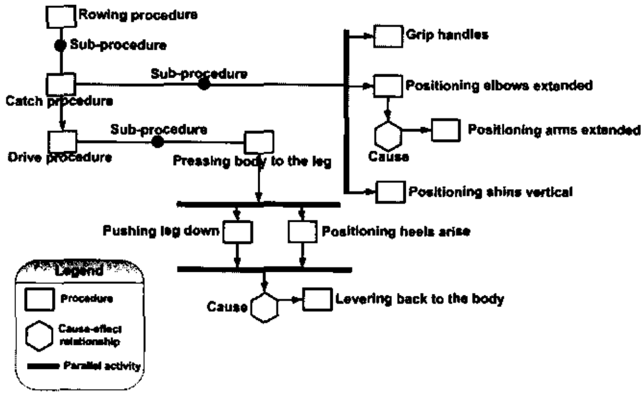

Figure 3. Task analysis of rowing procedure

Figure 4 and Table 1 represent some rowing ILOs based on the competency model used.

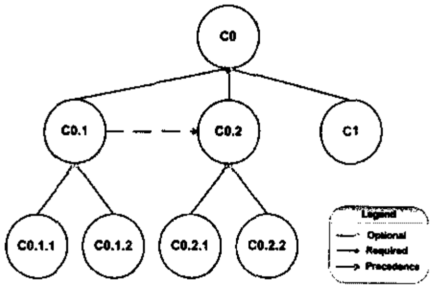

Figure 4. Conceptual model of leaning outcomes in the motor skill domain

TABLE I. SOME EXAMPLE ROWING LEARNING OUTCOMES

LO Num	Capability	Subject Matter
C0	Perform automatically	Rowing
C1	Articulate	Rowing
C0.1	Perform automatically	Catch
C0.1.1	Perform automatically	Grip handles
C0.1.2	Perform automatically	Position shins
C0.2	Perform automatically	Drive
C0.2.1	Perform automatically	Push leg down
C0.2.2	Perform automatically	Press body to the leg

The simplest competency structure consists of a pair of procedural skills, one subordinate to the other. The competency structure describes what the learner must be able to do before something else can be learned. The learning relation is identified by the following sentence: "A learner must be able to do 'X' in order to be able to do 'Y'." For example, in order to achieve C0 (perform rowing automatically), it is required for the athletes to achieve C0.1 (catch automatically), C0.2 (drive automatically), and C1 (articulate rowing). In order to achieve C0.1 (catch automatically), athletes should be able to demonstrate either C0.1.1 (grip handles automatically) or C0.1.2 (position shins automatically). The achievement of C0.1 (catch automatically) allows athletes to proceed to C0.2 (drive automatically). This shows that we can effectively map these more complicated learning outcomes using the competency model.

V. Conclusion

The design and development of effective teaching and learning activities may be based on ILOs. Training activities deal with learning outcomes in the motor skill domain, encompassing skills that require the use and coordination of skeletal muscles, whose outcomes are reflected in the rapidity, accuracy, force, or smoothness of bodily movement. The paper has shown that implementation of effective CBST may be based on a pedagogical approach that emphasises the attainment of ILOs.

Future work includes implementing a prototype system to map required and acquired ILOs in generating a gap analysis of an athlete's performances. We believe the proposed approach will assist athletes in finding a starting point and an efficient route through a structured learning sequence that will foster skill acquisition.

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