Searching for a methodology to bridge the gap between ideas and practice: An investigation of the sensorimotor mode of learning

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Abstract

The processes underpinning a specific 'idea', namely, how the assessment of the quality of movement within the sensorimotor mode of learning can be undertaken within a Structure of Observed Learning Outcomes (SOLO) framework, is described. The sensorimotor skill under examination is the 'forward roll' in gymnastics.

Firstly, a review of the pertinent literature was undertaken. This involved a search for the relevant fields of study and reporting the trends and findings, as well as the identification of a conceptual framework. Secondly, data were collected, in the form of digital videotapes, for three cohorts: children, young adults and older adults (N = 117) as they performed the forward roll. These data were analysed, which resulted in the development of a new framework, for the purpose of measuring the quality of the sensorimotor skill under investigation. Thirdly, the underlying construct of the new framework was verified by applying the Australian Council for Educational Research 's (ACER) *Quest* statistical technique, commonly known as Rasch. Finally, using the underpinning principles established during data analysis, a re-examination of the data from a SOLO perspective is currently being undertaken.

Introduction

> *The entire purpose of the human brain is to produce movement. Movement is the only way we have of interacting with the world. All sensory and cognitive processes may be viewed as inputs that determine future motor outputs.*
> *Wolpert et al. (2001, p. 478)*

This study is concerned with the way people move. The initial question is: 'How can one assess the quality of movement, within the sensorimotor mode of learning, for individuals, across the lifespan?' The purpose of this paper is to inform the reader about the work in progress aimed at attaining an answer to this question within a Structure of Observed Learning (SOLO) model of learning.

As a preliminary step in this investigation, an initial framework illustrating the 'research process' was envisaged. This framework is outlined in Figure 1.

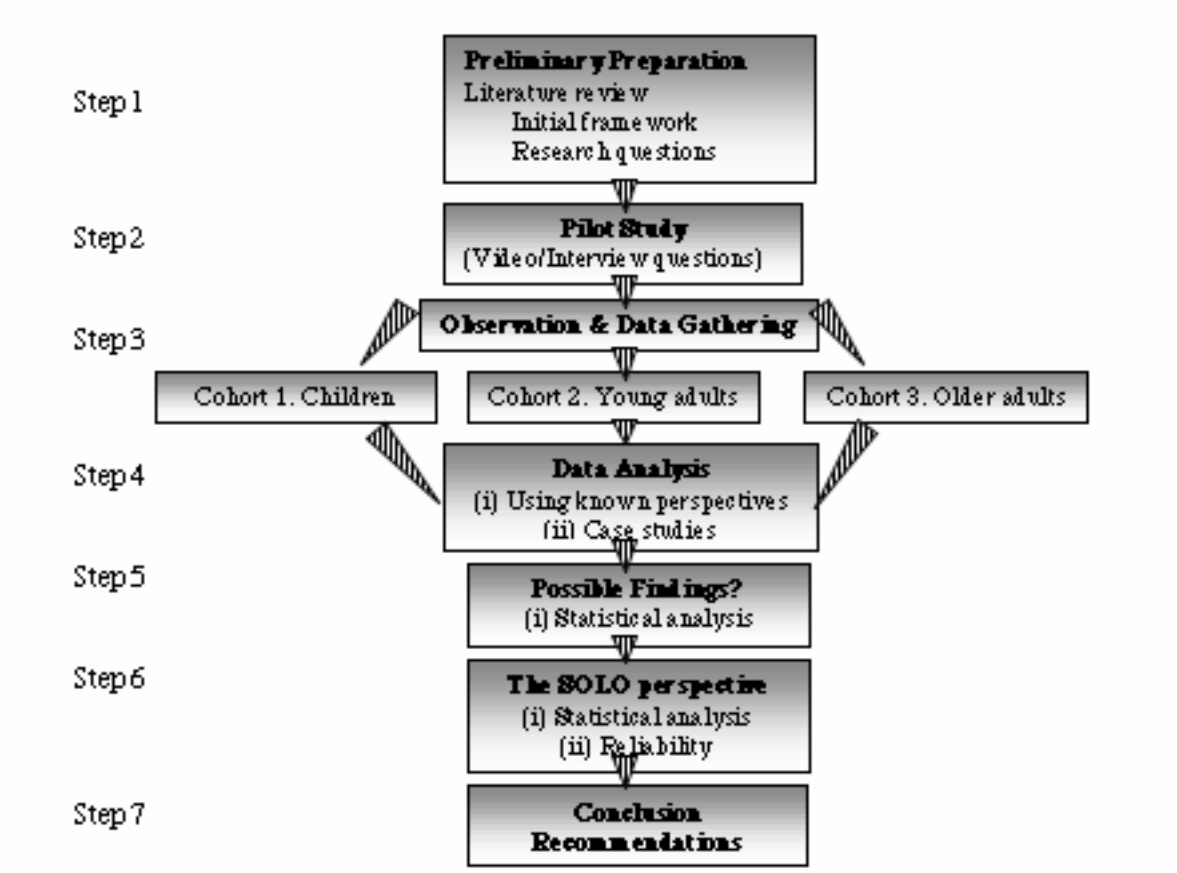

Figure 1: *Research Guide*

By following the direction of the arrows provided in Figure 1, the steps used to guide the research are outlined. A preliminary guide is useful, because it gives both direction and form to the investigative process. In addition, a starting point emerges.

The search for information and knowledge pertaining to the proposed investigation commenced with a three-pronged approach, delineated in Step 1 in Figure 1. Reference lists of several well known, and 'apparently' relevant (to the first author) texts were scrutinised. From these texts, lists of references (perceived to be relevant to the question) were constructed. Once the texts were procured, information applicable to the research theme was gathered. This step, whilst selective, was in the latter part of the research endeavour, a random process given the plethora of information and knowledge pertaining to the chosen theme. Secondly, the Internet, via a variety of search engines, was scrutinized. For example, words such as, outcomes, learning, measurement, and various combinations of these, to name but a few, were 'fed into the ether'. The third source of information comprised the advice and knowledge offered by the two persons given over to the task of supervising this thesis, whose advice was 'write something!'

From this intensive process the issue related first topic of the investigation evolved. The quest was to assemble information pertaining to learning theories in general, learning theories associated with human movement and measurement. Background information related to learning theory was necessary to gain an understanding of, and knowledge about, what 'was' and compare and contrast it with the present 'state of knowledge', i.e. what is now! Where to begin? A constructivist approach to learning emerged as a starting point, and what better way to start than with the apparent 'father' of constructivism, Jean Piaget.

Preliminary Preparation: Learning Theories

Piaget (1952) considered that sensorimotor skills could be observed from a developmental perspective. The assertion was that the sensorimotor stage of learning was the precursor to the cognitive development of an individual (child). Piaget (1952) promulgated a constructivist's view of learning, i.e. a view that purports a learner's view of the world, is founded on the concept that the individual constructs meaning about various events and experiences. This view implies that knowledge does not exist without the individual attaching meaning to that knowledge.

Both Dewey (1938) and Vygotsky (1997) supported the concept of constructivism. Dewey (1938) contributed to this approach by providing input regarding the importance of the actual learning environment in the learning process. Vygotsky (1997) considered that past learning was significant for future learning. Both authors recognised the importance of the sensory motor aspects of development, but did not pursue an investigation of its role in the development of the individual.

Piagetian theory was based on the concept that the learner 'passed through' a number of stages on the way to becoming a fully developed individual. There have been several more recent, in chronological terms, stage theories. For example, Case (1985) provided a model of learning, which included a sensorimotor stage. Fischer (1980) implied that Piaget (1952) placed too much emphasis on the maturational factors affecting the learning process to the detriment of the apparent importance of the environment. Mounoud (1986) considered the importance of genetic inheritance in the development of the individual, including the sensorimotor organisational processes, thus suggesting, the child developed sensorimotor records resulting from interactions with the environment.

Generally learning theories equate improvements in learning with age. However, the neo-Piagetian model proposed by Biggs and Collis (1980) contended that the age at which an individual (child) attained a certain stage was not necessarily a true indicator for that stage. Biggs and Collis' (1980) SOLO model highlighted four possible paths of development. It is noteworthy that the model's foundational mode, i.e. the sensorimotor mode is thought to be available across an individual's lifespan. Their SOLO model comprises a number of modes of learning that are hierarchal.

The SOLO modes of learning are termed: the sensorimotor, ikonic, concrete symbolic, formal and post formal. Biggs and Collis (1980) identified differences in performances within these modes and these differences were termed 'levels'. Levels demonstrate an hierarchy in the learning of a task from an incomplete to an expert performance. The levels are termed, unistructural (U), multistructural (M) and relational (R). Biggs & Collis (1980) referred to the progression of an individual, through these levels as a 'learning cycle'. Cycles have been identified and investigated within a number of modes, especially in the areas of mathematics and science education, but have not been explored for the sensorimotor mode.

Preliminary Preparation: Motor Learning Perspectives

Preliminary preparation, whilst keeping in mind the 'big picture' associated with learning theories, required an examination of motor learning perspectives. What was the literature saying about theoretical perspectives pertaining to motor learning?

Firstly, the maturationist's perspective, espouses the view that motor development occurs as a result of an unfolding of a ' master plan' existing within the genetic structure of the individual. This theory was developed from the work of Hall (1904), Gesell (1928) and McGraw (1935), but was later modified to take the environment into account as a factor in motor development.

Secondly, there have been a number of cognitive theories relating to the attainment of motor skills. These theories professed that motor learning resulted from cognitive events, and that the brain played a major role in an individual's motor development and movement choices. Notables amongst the realm of cognitivists are Adams (1971) Schmidt (1991), Connolly (1970), Kephart (1971) and Willingham (1998).

Thirdly, the concept of Dynamic Systems Theory (DST) was supported by a number of researchers, including Bernstein (1967), Kelso (1982) and Kugler and Turvey (1986), as a way of explaining movement outcomes. The basis of this approach to motor development involved the idea that the human body is comprised of a number of self-organising systems, which respond to environmental task demands to produce a movement. This theory has gained significance amongst researchers including Ulrich, Roberton, Langendorfer and Gallahue (personal communications 2003) as an acceptable theory for the explanation of movement responses.

How do these learning theories translate into practicality? Fitts and Posner (1967) addressed questions pertaining to motor skill learning through the use of a three phase model. In contrast, both Adams (1971) and Gentile (1972) proposed two stage models, which were similar in concept to the Fitts and Posner (1967) model, but used different terminology to describe the process. Vereijken (1991) proposed a three-stage

model, which implied that a learner attempted to manage the dynamics of the movement to solve a movement problem. Differing from the previous models, Graham et al. (1998) took a 'teaching approach', developing a four stage model involving observable characteristics of generic levels of skill proficiency.

Further exploration of the literature revealed that some researchers explored the psychomotor domain of the Bloom et al's (1956) Taxonomy as a way of explaining movement. Bloom et al. (1956) did not provide details relating to this domain, however, descriptive models were devised by others such as Dave (1975), Corbin (1976), Harrow (1972) and Simpson (1972).

Preliminary Preparation: Measuring Movement

Having attained a good working knowledge relating to learning theories and how motor learning and skill acquisition takes place; attention was now refocused on the issues surrounding measurement. Those procedures employed to measure the sensorimotor mode movement, i.e. human movement, were selected for further investigation. Issues surrounding the origin and history of testing and measurement, as well as assessment and test theory were also examined. However, space precludes a full discussion of these issues. Notwithstanding, the main emphasis, in this paper is placed on the measurement of movement. One reason for choosing the forward roll in gymnastics as the main object for observation was based on the author's prior knowledge and experience as a qualified gymnastics coach and Physical Education Specialist teacher. The second, and probably more valid reason, was that it is one of the few motor skills that has been validated in terms of its developmental characteristics (Williams 1980). Her work was based on the developmental sequences of Roberton & Halverson (1984).

Measurement perspectives: The Forward Roll

The process employed by gymnastics judges to score performances was familiar to the principal researcher. The method consists of deducting points for performance errors, from a hypothetical maximum score. This method of scoring has been accepted as the standard for competition performances in gymnastics (Australian Gymnastics Federation 2002).

What emerged from an analysis of the literature, however, was that a number of other perspectives have been used to assess the performance of the forward roll (and other motor skills). Firstly, there was a skill-based description of the ideal forward roll, based upon biomechanical principles as described by George (1980). Secondly, a developmental stage model was proposed by Gallahue and Ozmun (1998). This latter model was founded on three stages of development, the initial, elementary and mature. Thirdly, a level of proficiency model, based on four levels of ability, was reported by Graham et al. (1998). The levels were

termed the precontrol, control, utilisation and proficiency. Lastly, the phases of the forward roll, were derived from the component approach of analysis of motor skills initiated by Roberton and Halverson (1977).

Preliminary Preparation: Research Questions and Initial Framework

With the establishment of the basic foundations of the task, i.e. the ideas of educational theorists, motor learning perspectives, and how the measurement of movement, specifically for the forward roll was undertaken, the next step was to formulate the research questions, and gather and analyse data.

Research Questions

Prior to data gathering the research questions were established:

- Research Question 1: Are the observable components for the forward roll the same for children, young adults and older adults?
- Research Question 2: Is the SOLO model an appropriate tool for assessing subjects' performances, representing a diverse developmental range, as they demonstrate competency in the forward roll?
- Research Question 3: Can SOLO provide an assessment framework for the forward roll?

The search for an appropriate initial conceptual framework on which to base the research ended when Knudson and Morrison's (1997) model was found to be both appropriate and useful for the qualitative analysis of human movement.

Initial Framework

The Knudson and Morrison (1997) model includes a task list, namely, preparation, observation, evaluation/diagnosis, and intervention. Furthermore, it is a comprehensive, integrated model that lists issues associated with each of these four tasks. All of the model's tasks were retained, i.e. 'Intervention'. This was deemed necessary as it relates to the applicability to the sensorimotor mode of learning. Figure 3 shows the initial framework used to scaffold the research.

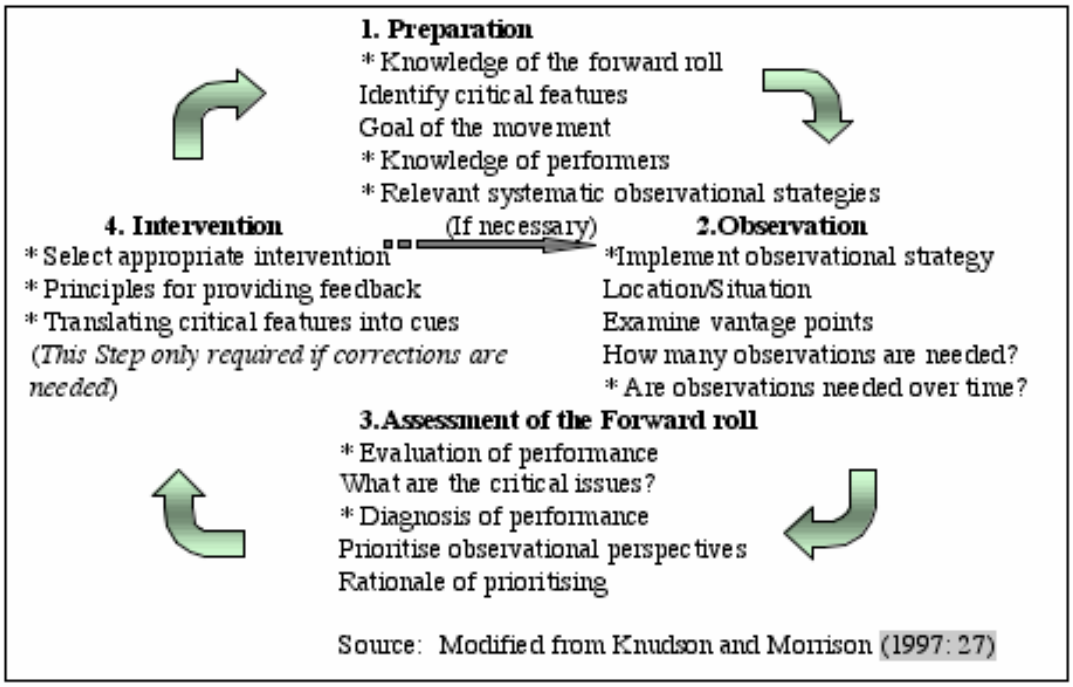

Figure 3: *A Comprehensive, Integrated Model of Qualitative Analysis*

This model shows four phases. Undertaking these moved the research forward from Step 1, the Preliminary Preparation as outlined in the research guide (Figure 1), into Step 2 the Pilot Study, which aligns with the second stage of the Knudson and Morrison (1997) model.

Pilot Study: Preparation Step

Step 2, of the research involved a number of issues including, having knowledge of the elements of the forward roll, the ability to identify the critical features, as well as identifying and solving a number of technical issues pertaining to data collection, namely video recording procedures. The following paragraphs describe, in attenuated form these issues.

Ethics approval from UNE was obtained prior to data collection and trailing data gathering techniques. 'Beachside'[8] was the site chosen to practice these techniques, such as videotaping, interviewing and questioning. This site represented and 'ecologically valid' environment, i.e., one where children would 'normally' perform such skills (Miller 2001).

The purpose of trialling data research skills at Beachside was threefold. Firstly, it was to ensure the eventual target group understood the questions (Borg & Gall 1989, p. 445), secondly to avoid exposing that group to

[8] Beachside is the pseudonym used for a gymnastics club in the Coffs Harbour area of NSW

the actual questions, and thirdly, to trial camera positions whilst the subjects were performing the forward roll. Camera angles and positioning were largely exploratory.

Interviewing participants (supervised by an experienced researcher JM[9]) permitted information to be gathered concerning a number of issues, including what each subject thought about just prior to their performance, what they considered to be the characteristics of a forward roll, plus what might be the characteristics of a well executed forward roll. This data has the potential to assist with the exploration of the modes of the SOLO model.

Observation and Data Gathering

Step 3 of the research guide includes observation of the subjects and data gathering. The two primary data collection sites included the rural township of Whitestone•, population 9,000) where data pertaining to children were collected. The rural city of Hilltop• was the data site for young adults and older adults.

Data Gathering

Step 3 involved data collection from three cohorts from a broad age range. Cohort 1, comprised children whose age was less than 17 years. Cohort 2 included young adults, aged from 17 to 22 years. Cohort 3 comprised older adults whose age was over 23 years. Performances of the forward roll were recorded in the first instance using a hand-held Panasonic digital video camera. All the videotaped materials were converted to compact disc (CD), MPEG which permitted individual 'frame by frame' observation of the subjects, with the added benefit of having a time reference calibrated in tenths of a second.

In addition to videotape recordings, audiotapes of interviews of selected young adults and older adults were conducted. The interview data was transcribed and emerging themes noted (Cohen & Manion 1992). Additional information, including the name, age and time-span since each subject had previously performed a forward roll, was gathered.

Collection of the videotape data for Cohort 1 (children) occurred, on a number of occasions, during the time period when the subjects were involved in their normal gymnastics program at the Whitestone Gymnastics Club.

[9] JM (PhD Physical Education)
• Not real name

Cohort 2 (young adults) consisted of three sub-groups. One sub-group included University students enrolled in the first semester of their first-year of study. The second sub-group included first-year University students enrolled in the second semester. The third sub-group included students enrolled in an elective Physical Education unit of study. All subjects from these sub-groups were enrolled in a Bachelor of Education/Bachelor of Teaching degree at the University. It was considered, that these three sub-groups would be representative of the range of movement experiences for the young adult cohort.

Gathering data from older adults employed the same procedures as for the young adult cohort. Data was collected from older adults, termed Cohort 3. This took place over several days, and involved a number of separate sub-groups. Each sub-group from this Cohort was identified. One sub-group included those subjects who attended a residential school during one particular year. The second sub-group consisted of residential school participants from the following year. Students attending residential classes usually reside outside the immediate Hilltop• area and originate from locations both within Australia and occasionally overseas. These attending students were provided with brief outlines of the proposed study and subsequently invited to participate.

Data Analysis

Using George's (1980), gymnastics approach to assessment of the forward roll, all subjects (N = 117) were analysed, and subsequently divided into three groups representing low, medium and high quality performances.

Case Studies

From each of the three groups, three individuals representing each cohort, one from each level of quality were analysed in depth (n = 9), using the four assessment perspectives. Namely, gymnastics approach, Gallahue and Ozmun's (1998) stages of development method, Graham et al's. (1998) levels of proficiency, and Roberton and Halverson's (1977) phases perspectives. Following this in-depth analysis some shortcomings were noted when the criteria for each perspective were applied across the different cohorts. Table 1 summarises the findings of three of the case study examples.

Table 1: A Comparison of Four Perspectives for Assessing the Forward Roll: An Example Using Three Case Studies

Subject Number	Gymnastic (Skill) *(George)*	Stages of Development *(Gallahue & Ozmun)*	Levels of Proficiency *(Graham et al)*	Phases *(Roberton & Halverson)*
Children				
1	Low	Between Initial & Elementary	Between Precontrol & Control	I (i) Step 2 (ii) Step 1 C (i) Step 2 (ii) Step 1
Young Adults				
5	Medium	Mature	Control (No data for Proficiency)	I (i) Step 3 (ii) Step 3 C (i) Step 3 (ii) Step 3
Older adults				
9	High	Beyond the scope of this Perspective	Control (No data for Proficiency)	I (i) Step 2 (ii) Step 2 C (i) Step 3 (ii) Step 3

The information contained in Table 1 shows that, for each perspective, there was a discrepancy between the measurement criteria and the performance of the forward roll. For example, for the 'stages of development' perspective subjects were judged to be 'between' stages or the instrument did not cater for a particular individual. A similar scenario existed for the levels of proficiency model. The 'phases' model shows individuals operating at different positions within a phase.

In order to overcome the perceived shortcomings of the various perspectives, further analysis of all subjects was undertaken. This process led to the emergence of three hypothesised sequences within the rolling action, namely, beginning, bridging and end. A refereed paper providing more details of these processes has been accepted for publication (Haynes & Miller 2006). In addition, observational cues were developed, which were useful for determining the quality of an individual's performance of the forward roll. These cues were termed, *indicators* and *descriptors.* The *indicators* are the position of the various body parts (components) within each sequence. The *descriptors* are the subdivisions within each *indicator* used to portray and differentiate the range of movement quality.

Four indicators emerged from the data analysis for the beginning sequence, with two to four descriptors for each indicator. There are two indicators for the bridging sequence, which have three and four descriptors respectively. For the end sequence there are three indicators with two to four descriptors. See Figure 4 for an example of a descriptor and indicators for the 'hand position' for the beginning sequence.

The following Pictures 6.1(i), (ii) and (iii) in Figure 4 illustrate the three *descriptors* for *indicator* 1 of the *beginning* sequence of the forward roll.

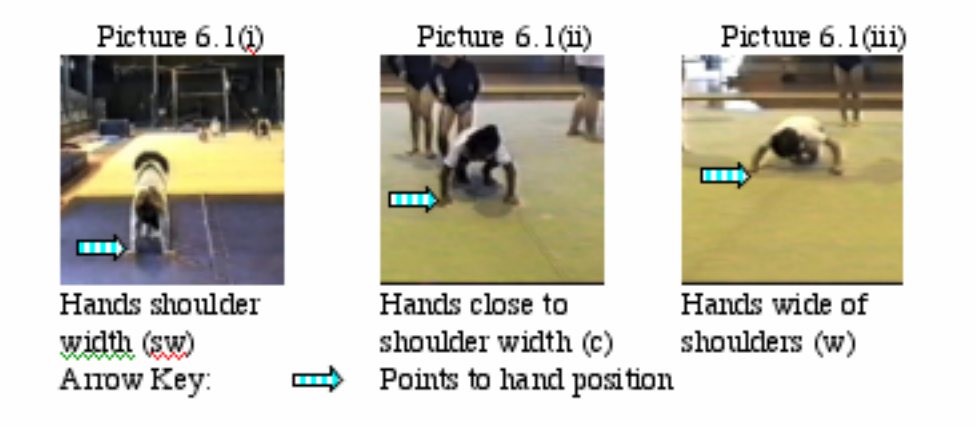

Figure 4: *Hand Position Indicator Descriptors*

Figure 4 shows the first *indicator*, namely, the position of the hands on the surface, i.e. their location lateral to the sagittal plane. The sagittal plane is an imaginary line lengthwise through the body running from front to back. The body is therefore divided into left and right sides (Tortora & Anagnostakos 1990, p. 9).

Preliminary Findings

Step 5 in the research includes an exposé of the possible findings that emerged from the data analysis. To this end, firstly, a new framework emerged from the data analysis, which illustrated the mechanism by which an investigation of the quality of movement could be obtained across all cohorts. By following the steps outlined in this framework, one is able to determine the quality of the skill under scrutiny, namely, the forward roll.

Secondly, a new and innovative way of presenting the output from *Quest* (Adams & Khoo 1993) was devised, using pictorial data. The presentation of data using pictures, being substituted for numbers, allows the reader to be able to see what the performance of an individual at a pre-determined level of quality looks like. However, when the pictures are substituted none of the veracity of the statistical information is compromised. This means that the placements of the pictures on the statistical map appear in the same locations, as did the numbers.

Figure 5 provides a description of the Framework used to determine the quality of movement for the forward roll.

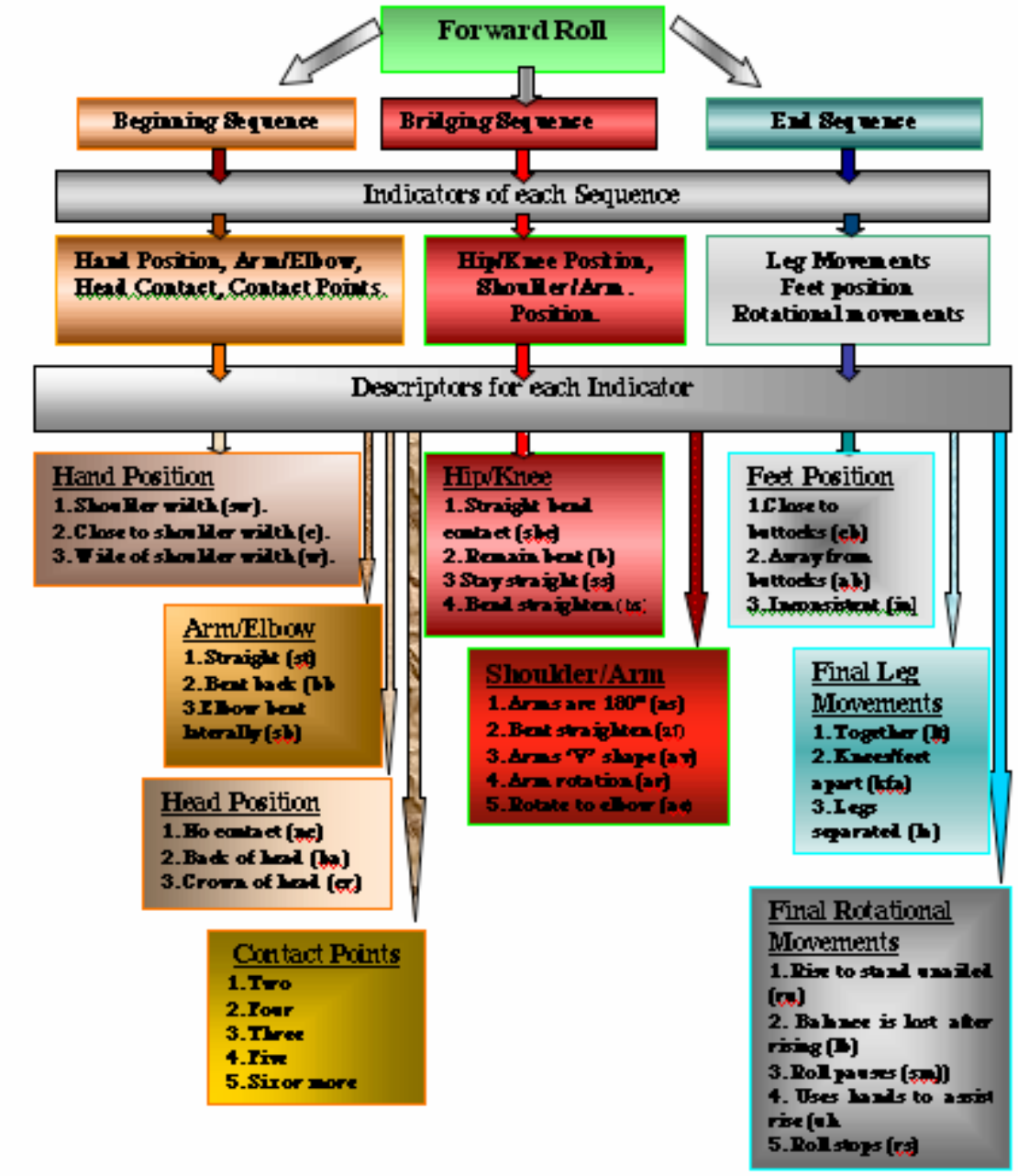

Figure 5: *A Model for Assessing Movement Quality of the Forward Roll (Haynes et al.2005)*

Figure 5 presents an overview of the instrument derived from the qualitative analysis of the forward roll. The information accompanying each arrowed link informs the process of analysis and provides a broad template for assessment. Working through the model, commencing with the three sequences of the forward roll, the beginning, bridging or end, by following the arrows to the *indicators* and then to the *descriptors* for each sequence, one can begin to determine the quality of a performance.

A more detailed account, of the Framework presented in Figure 5, and for the Rasch (1960) analysis, is available elsewhere (Haynes et al. 2005). However, it should be noted that the Framework, which emerged from the data represents an assessment instrument, which is sufficiently fine-grained to be applied across all cohorts.

Statistical Analysis: Rasch

In brief, 'Rasch measurements are particularly suited to investigations in the wide range of human sciences' (Bond & Fox 2001, p. 189), which according to these authors is the only technique generally available for constructing such measures. The software package used to calculate the Rasch (1960) scales is termed *Quest,* (Adams & Khoo 1993) which is useful for gaining an understanding of the processes underlying the reason why people and specifically selected items behave as they do.

> *When a variable indicating a single particular construct has been identified, within a targeted population, the measurement of the subject's ability is independent of the set of items that were administered, and the item difficulty is independent of the set of persons used to calibrate the item.*
>
> *Snyder & Sheehan (1992, p. 88).*

'Movement quality' is the underlying construct of the Framework presented in Figure 5. Output from *Quest* (Adams & Khoo 1993), using the partial credit form, which specifically incorporates the possibility of having differing numbers of steps for different items on the same test (Masters 1982) revealed that both items and persons were shown to behave in a predictable manner. It is realistic, therefore to suggest that the applicability of the new Framework is worthy of continued investigation within the field of movement studies. Thus, based on the acceptable levels of the fit statistics, the case estimates could be used to explore additional aspects of group performance, such as differences between the qualities of movement for each cohort, using multivariate techniques.

Innovative Data Presentation

The output from *Quest* (Adams & Khoo 1993) is normally portrayed in what are termed 'maps'. The measurement unit of these maps is the logit, which is the common unit for both person movement quality and items. Persons and items are located on the map according to their movement quality and difficulty estimates, respectively. Logit information is displayed down the far left hand side of the map. Because it is a logit scale, i.e. an interval scale, the equal distances up and down that scale have equal value. Down the centre-left of the map 'Xs' represent the distribution of case (subject) estimates on the logit scale. Each 'X' represents the estimate for one subject, which signifies a 50% probability the subject will be able to achieve

that item (*descriptor*) at the same position on the logit scale. Numerals on the right hand side of the map show step difficulties.

Notwithstanding, the opportunity existed to present the map in pictorial format. This method allows the reader to quickly scrutinise the 'form', in this case, of the person performing the forward roll.

Figure 6 presents an example of the pictorial format, for one *indicator*, namely, hand position and the descriptors which are used to discriminate the quality of a performance, for the beginning sequence of the forward roll.

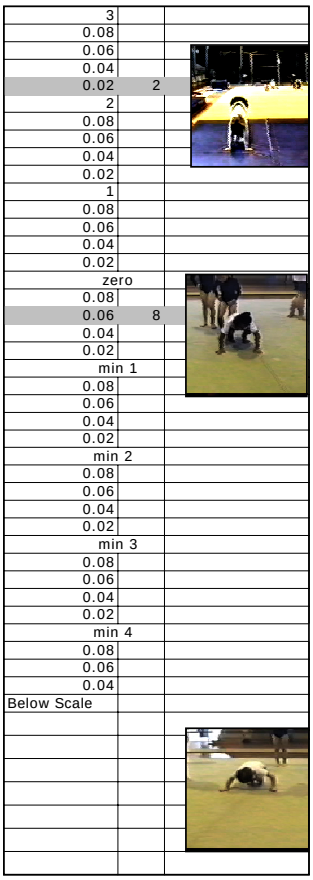

Figure 6: *Item-person Fit Map*

Figure 5 shows a segment of the item person fit map, generated using *Quest* (Adams & Khoo 1993). These data are generally shown as a map, however, pictures are employed to replace numbers.

In summary, the numerals shown in the left hand column of Figure 6 are termed logits. The distance between each picture of a gymnast, illustrating hand position *descriptors*, can be calculated in terms of the number of logits between them. Numbers have replaced 'Xs'. For example, the picture at the bottom of Figure 6 represents the lowest quality *descriptor* for the *indicator* of hand position, the middle picture better

quality and the top picture the highest quality performance (the bottom picture is actually below the logit scale, as generated by *Quest*, (Adams & Khoo 1993) but is included for illustrative purposes).

The important implication is that the number of logits between each picture represents the degree of difficulty of moving from one *descriptor* for the hand position to the next. In this case it is much easier to move from the middle position to the top position than it is to move from the lowest position to the middle position.

With reference to the above Figure the remainder of the pictorial data for all indicators, descriptors for each sequence was presented at the International Council for Health, Physical Education, Recreation, Sport & Dance (ICHPER-SD) (Haynes 2006).

Future Findings: SOLO

From a SOLO perspective, the *descriptors* also form the basis for coding the movement quality data. An examination of the SOLO cycles in the sensorimotor learning mode is currently under investigation, i.e., Step 6 in the research process. It is sufficient to say that, preliminary analysis using the information gleaned, from the use of the new Framework, showed that a SOLO perspective of the forward roll is feasible. Thus far, exemplary case studies have been forthcoming from which SOLO cycles have been tentatively examined. In addition, Rasch (1960) analysis, as well as intra- and inter-rater reliability checks have been conducted.

Conclusion

In searching for a methodology to bridge the gap between ideas and practice a Framework (Haynes et al. 2005) emerged which is instrumental in this endeavour. A good mixture of the processes, introduced via the research guide, with the steps outlined in Knudson and Morrison's (1997) initial framework, led to the creation of an artifact that answered the original question; the question that arose from an 'idea'.

This study has produced some edifying results, and contains a number of features, which differentiate it from prior investigative studies. The use of three cohorts from differing age groups is a feature that has not been attempted in earlier research concerning the quality of movements for the forward roll. The Framework (Figure 5) that explains the pathways involved in the analysis of the forward roll is unique to this study. The use of Rasch (1960) modelling, via *Quest* (Adams & Khoo 1993) software, to analyse the quality of movements has not been employed in research concerning the investigation of levels of quality of performance for the forward roll. With further research and analysis a SOLO explanation of the sensorimotor mode of learning may be forthcoming. If the findings either confirm or deny a SOLO explanation for this mode, there is the potential to add information of a highly significant nature to the conceptual framework of that model.

REFERENCES

Adams, J. A. 1971, A closed loop theory of motor learning, *Journal of Motor Behavior,* vol.3, pp.111-149.

Adams, R. J. & Khoo, S. 1993, *Quest - The Interactive Test Analysis System,* ACER, Hawthorne, Victoria.

Australian Gymnastics Federation 2002, A History of Australian Gymnastics 2002, Retrieved from http://www.gymnsw.org.au/history_australia.html

Bernstein, B. 1967, The Co-Ordination and Regulation of Movements, Pergamon, Oxford UK.

Biggs, J. & Collis, K. 1980, 'The solo taxonomy', *Education News,* vol.17, no.5, pp.19 - 23.

Bloom, B. S., Englehart, M. D., Furst, E. J., Hill, W. H. & Krathwohl, D. 1956, *Taxonomy of Educational Objectives: The Cognitive Domain*, McKay, New York.

Bond, T. G. & Fox, C. M. 2001, *Applying the Rasch Model; Fundamental Measurement in the Human Sciences*, Lawrence Erlbaum Associates, Mahwah New Jersey.

Borg, W. R. & Gall, M. D. 1989, *Educational Research: An Introduction,* 5th edn, Longman, New York.

Case, R. 1985, Intellectual Development, Birth to Adulthood, Academic Press.

Cohen, L. & Manion, L. 1992, *Research Methods in Education* 3 ed., London: Routledge, Orlando Florida.

Connolly, K. J. 1970, *Mechanisms of Motor Skill Development*, Academic Press, London.

Corbin, C. B. 1976, Becoming Physically Educated in the Elementary School, Lea & Febiger, Philadelphia.

Dave, R. H. (ed) 1975, *Developing and Writing Behavioral Objectives*, Educational Innovators Press, Tuscon AZ.

Dewey, J. 1938, *Experience and Education*, Macmillan, New York.

Fischer, K. W. 1980, 'A theory of cognitive development: The control and construction of hierarchies of skills', *Psychological Review,* vol.87, no.6, pp.477-531.

Fitts, P. M. & Posner, M. I. 1967, *Human Performance*, Brooks-Cole, Belmont CA.

Gallahue, D. L. & Ozmun, J. 1998, Understanding Motor Development Infants, Children, Adolescents, Adults, 4th edn, McGaw-Hill, Boston.

Gentile, A. 1972, 'A working model of skill acquisition with application to teaching', *Quest,* vol.17, pp.3-23.

George, G. 1980, *Biomechanics of Women's Gymnastics*, Prentice Hall, Englewood Cliffs, NJ.

Gesell, A. 1928, *Infancy and Human Growth*, Macmillan, New York.

Graham, G., Holt/Hale, S. A. & Parker, M. 1998, *Children Moving: A Reflective Approach to Teaching Education*, 4th edn, Mayfield Publishing Company, Mountain View, CA..

Hall, G. S. 1904, *Adolescence,* Vol. 1 & 2, Appleton-Century-Crofts, New York.

Harrow, A. J. 1972, *A Taxonomy of the Psychomotor Domain*, David McKay Co., New York.

Haynes, J. 2006, Objective measurement using pictorial data, Proceedings of Fusion Down-under Recipes for Movement: Challenging perspectives and constructing alliances, ICHPER-SD, Wellington NZ.

Haynes, J. & Miller, J. 2006, 'Differences and similarities between the performance of a fundamental skill in gymnastics for three cohorts: Children, young adults and older adults', *Proceedings of Australian Association for Research in Education. HAY 06512*, AARE, Adelaide SA.

Haynes, J., Miller, J., Callingham, R. & Pegg, J. 2005, 'Applying item response modelling to confirm the underlying construct of a new process instrument in gymnastics', *Refereed Paper at the Australian Association for Research in Education*, www.aare.com.au HAY 05720, Parramatta.

Kelso, J. A. S. (ed) 1982, *Human Motor Behaviour: An Introduction*, Erlbaum, Hillsdale, NJ.

Kephart, N. C. 1971, *A Slow Learner in the Classroom*, Merrill, Columbus, OH.

Knudson, D.V. & Morrison, C. S. 1997, *Qualitative Analysis of Human Movement*, Human Kinetics, Champaign, IL.

Kugler, P.N. & Turvey, M.T. 1986, Information, Natural Law, and Self-Assembly of Rhythmic Movement, Erlbaum, Hillsdale, NJ.

Masters, G.N. 1982, A rasch model for partial credit scoring. *Psychometrica,* vol.47, no.2, pp.149-174.

McGraw, M.B. 1935, *Growth: A Study of Johnny and Jimmy*, Appleton-Century, New York.

Miller, J. 2001, The product and performance of the two handed sidearm strike for primary school-aged children: The interrelationship of coordination, age and gender, Unpublished Doctoral Thesis, New England, Armidale.

Mounoud, P. 1986, Similarities between developmental sequences at different age periods, in *Stage and Structure: Reopening the Debate*, ed I. Levin, Ablex, Norwood NJ, pp. 40-58.

Piaget, J. 1952, *The Origins of Intelligence in Children*, International Universities Press, New York.

Rasch, G. 1960, *Probabilistic Models for some Intelligence and Attainment Tests* Expanded edition, University of Chicago Press, Chicago MI.

Roberton, M. A. & Halverson, L. 1977, The developing child — his changing movement, in *Physical Education for Children— A Focus on the Teaching Process,* ed B. Logsdon, Lea & Febiger, Philadelphia.

Roberton, M. A. & Halverson, L. 1984, *Developing Children - Their Changing Movement A Guide for Teachers*, Lea & Febiger, Philadelphia.

Schmidt, R. A. 1991, Motor Learning and Performance: From Principles to Practice, Human Kinetics Books, Champaign IL.

Simpson, E. J. 1972, The Classification of Educational Objectives in the Psychomotor Domain, Gryphon House, Washington.

Snyder, S. & Sheehan, R. 1992, The rasch measurement model: An introduction, *Journal of Early Intervention,* vol.16, no.1, pp.39-53.

Tortora, G. J. & Anagnostakos, N. P. 1990, *Principles of Anatomy and Physiology*, Harper and Row, New York.

Vereijken, B. 1991, *The Dynamics of Skill Acquisitio,* Unpublished PhD, Free University Netherlands, Amsterdam.

Vygotsky, L. S. 1997, *The Collected Works of L S Vygotsky*, Springer, New York.
Williams, K. 1980, 'Developmental characteristics of a forward roll', *Research Quarterly for Exercise and Sport,* vol.51, no.4, p.703.

Willingham, D. B. 1998, 'A neuropsychological theory of motor skill learning', *Psychological Review,* vol.105, no.3, pp.558- 587.

Wolpert, D. M., Ghahramani, Z. & Flanagan, R. J. 2001, 'Perspectives and problems in motor learning', *Review TRENDS in Cognitive Sciences,* vol.5, no.11 November, pp.487-494.