A Method for Understanding Students' Perceptions of Concepts in the Defence in Depth Strategy

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ABSTRACT

The Defence in Depth strategy is a fundamental principle in the physical protection of the assets of an organisation. The robustness of the strategy has allowed it to be applied to a range of situations where assets need to be protected. This study seeks to examine the understanding of novice learners' perceptions of the defence in depth principles through the knowledge structure approach to concepts in the strategy. The multidimensional scaling (MDS) statistical technique has been applied to dissimilarity measures on a range of facilities according to the defence in depth functions of deterrence, detection, delay, and response. The barriers that correspond to these functions are considered as the analysis standard for the set of facilities.

Pre and post instruction knowledge structures have been developed for novice learners, and the knowledge structure for an expert group produced. The study indicates that novice learners knowledge structures become more like the experts structure with instruction.

Key Words: cognitive structures, knowledge structures, defence in depth, multi-dimensional scaling, MDS, understanding security concepts

INTRODUCTION

The *defence in depth* approach to the protection of assets is most familiar to security practitioners and operatives. The strategy has an extensive history of application and success in the prevention of theft, destruction of facilities, and the protection of personnel and information. Probabilistic models of the *defence in depth* principle have been developed to optimise the protection of assets in an organisation, and as a consequence the application of a range of barrier types to prevent unauthorised access is well understood.

Because of the robustness of the *defence in depth* principle, it has been applied in a variety of contexts ranging from physical security through to the protection of information. There is a need for students to understand the principle of *defence in depth* in its many applications, and be able to conduct appropriate analyses of penetration in the strategy. This study has conducted an investigation of a novel approach to the level of understanding of novices' perceptions of the concepts involved in the *defence in depth* principle.

The portrayal of knowledge structures for a discipline is an approach to research the *instruction – learning* paradigm for novice learners. Organisational and structural relationships among concepts may provide an understanding of the acquisition of concepts in memory, with a subsequent improvement in the instructional process. Although there are several approaches to the portrayal of knowledge structures, this study shall be concerned with those based on similarity, proximity or relatedness between concepts within the knowledge domain.

The paper describes a novel approach to understanding students' perceptions of concepts in a *defence in depth* strategy, and the development of these structures with instruction. Novice learner groups, both before and after instruction together with accumulated maturation with the *defence in depth* strategy, are compared to the knowledge structure of an expert group. The more alike are the knowledge structures of novice learners and the experts, then the more likely it is that learning has occurred.

DEFENCE IN DEPTH

The *defence in depth* strategy has been applied in the protection of assets for centuries, and the principle is based on the enclosure of an asset by a succession of barriers, all of which must be penetrated for the asset to be acquired. This approach to asset protection through a succession of barriers has been adopted as a strategy to restrict the penetration by unauthorised access to the assets, and hence gain time for the authorities to react to the penetration of the asset protection system (Smith and Robinson, 1999).

The functions of the barriers in the *defence in depth* strategy are those of deterrence, detection, delay, and response. These functions provide a range of types of barriers that maximise the probability of prevention of unauthorised access, and maximise the potential for detection and apprehension of unauthorised persons.

Deterrence: is achieved through signage, lighting, definitions of boundaries, and psychological cues.
Detection: if access has been gained by unauthorised person(s) then early detection of their presence is required to facilitate apprehension.

Delay: when unauthorised access to a facility has occurred, the physical barriers must be sufficiently substantial to delay the progress of the intruders.

Response: the delay time of the barriers to resist must be sufficient to allow an appropriate response team to attend the scene for apprehension.

These functions of the *defence in depth* strategy can be mapped onto the following types of barriers for the protection of assets (Smith and Robinson, 1999):

Psychological barriers: barriers that give clear warning to persons that a boundary should not be traversed, such as signs, lines, chains, fences, and lighting.

Electronic barriers: barriers to detect the presence of an intruder, such as CCTV, intrusion detection systems, and access control systems.

Physical barriers: the purpose of these barriers is to prevent physical access of the intruders to the asset, and include fences and walls, the envelope of the building, doors and windows, and safes and containers.
Procedural barriers: barriers that derive from security policy to maintain the integrity of the protection of assets, and include mobile guards, identification badges, sign in register, and proximity access control cards.

The defence in depth strategy has been operationalised to protect assets in facilities for a considerable duration, but has not been formalised with barrier types and functions. This study has investigated the perceptions of students of the major concepts of the *defence in depth* strategy in order to gain an insight into the understanding of this principle.

KNOWLEDGE STRUCTURES

The early cognitive researchers (Bruner, Goodnow, and Austin, 1956; Ausubel, 1966) have proposed that teaching effectiveness can be enhanced if the learner has memory structures appropriate for the instructional material. Cognitive models of human memory, such as information processing models, knowledge-assembly theory, and organisation theory all emphasise the necessity for structure in memory. Human long-term memory (LTM), like any large-scale data storage device, can have accessing and retrieval of information difficulties. A central aspect of the role of organisation of concepts in memory is considered to be related to the retrieval of information in recall.

The network of relations among concepts in LTM constitutes the substantive or subject matter structure of a particular cognitive domain, which is unique to the individual. The learning of the subject matter structure has been initially characterised by Michon (1972) as the acquisition of internal representations of external structures, and may be described by a network of relations between the concepts. A variety of studies using the structure of knowledge in a cognitive domain have been reported, including the fields of management, marketing, educational psychology, statistics, medicine, and physics (Gonzalvo, et al., 1994; Streveler, 1994; McGaghie, et al., 1998).

The task of the instructor is to assist with student acquisition into memory of the major concepts, so that the learner perceives *correct* relations between concepts of a discipline. It is assumed that the instructor knows the ideal organisation of concepts to be learned by a student, so that the function of *expert* instruction is to aid the learner to acquire the perceived knowledge structure of the instructor.

It can be argued that the experts of a discipline define the structural acquisition of concepts from the discipline; so that teachers, authors and researchers operating within a content domain perceive relations between concepts in a similar manner (Smith, 1986; Sireci and Geisinger, 1995). As the overall organisation of concepts in memory indicates the knowledge structure for a particular individual then a comparison of knowledge structures of learners and experts can reveal the extent of meaningful learning that has occurred. Koubek and Mountjoy (1991) showed this effect with subjects operating in the domain of clerical work, and Steinberg (1990) showed the novice – expert differences in knowledge structures in the domain of statistics.

MULTIDEMENSIONAL REPRESENTATION

Concepts can be *classified* by component properties, where the components of classification can be characterised by qualitative attributes called *features*, or quantitative attributes called *dimensions*. Thus a concept may be described by an extensive featural list indicating the attributes characteristic of the concept, or by a shorter list of dimensions which indicates how much of the attributes are present. Both approaches seek to indicate the degree of similarity between concepts (Smith, 1986).

This investigation uses the dimensional approach, which is a probabilistic representation of concepts, and where the dimensions are continuous attributes of the concept. Each dimension is represented as a continuous psychological dimension, with the different between two concepts being a matter of continuous degree on each defining dimension.

Concepts having the same relevant dimensions can be represented as points in a multidimensional metric space, where the defining dimensions are orthogonal. The relations between pairs of concepts that occupy positions in multidimensional space can be expressed as a distance parameter. This parameter can be used as a measure of similarity between concepts with respect to the defining dimensions of the space.

METHODOLOGY

Multidimensional scaling (MDS) configurations are representations of subjects' perceptions of similarity between the concepts in the knowledge domain. This study selected a range of facility concepts to be judged according to types of barriers in the *defence in depth* principle. These types of barriers of psychological, electronic, physical, and procedural barriers are derived from the functions of deter, detect, delay, and respond. The facility concepts selected are*: military base, supermarket, art gallery, suburban bank, research centre, university, primary school*. These facility concepts were chosen as they represent a large range of dissimilarity on the dimensions of knowledge space for the domain of the *defence in depth* principle.

Students enrolled in the Security Science course at Edith Cowan University were administered a dissimilarity instrument that required that they judge the similarity/dissimilarity between pairs of facility concepts according to each of the types of barriers in the *defence in depth* principle. That is, these novice learners were required to indicate the degree of similarity for the physical security between the facilities, where Figure 1 shows Art Gallery – Primary School, and University – Military Base facility concept pairs for similarity/dissimilarity rating.

Physical Barriers

	Unrelated	Highly Related
Art Gallery – Primary School	[---]	
University – Military Base	[---]	

Figure 1: Similarity/Dissimilarity rating scale for spatial distribution of facility concepts.

Students indicated the degree of similarity between each of the twenty-one pairs of facilities generated for the seven selected facility concepts. These indications of similarity, or dissimilarity, for each of the pairs of facility were completed for the four types of barriers in the *defence in depth* strategy.

The *defence in depth* concepts similarity instrument was completed by the following groups:

ten novice Security Science degree level students before instruction in Defence in Depth.
ten novice Security Science degree level students after instruction in Defence in Depth.
four Master of Science (Security Science) candidates as experts in Defence in Depth.

The data from the subject groups were collated in both individual and group averaged data in the form of dissimilarity half-matrices of the pairs of facilities. These data were analysed to examine the knowledge structures as indicators of understanding in the domain of the *defence in depth* principle.

ANALYSES AND INTERPRETATION

The analytical methodology was the Multidimensional Scaling (MDS) technique (Takane, Young, and De Leeuw, 1977) to obtain the single most satisfactory representation of the distribution of the concept facilities according to the barrier types for the knowledge structures. These structures were derived in 2-D representations for the pre and post novice instruction groups and the expert group. From these research groups, both *within* and *between* comparisons were conducted for groups and individuals.

The following analyses were performed to test the hypothesis of differences of understanding between expert and novice knowledge structures in the *defence in depth* principle of asset protection. These analyses were individually conducted for all barrier types for:

ten novice learners pre instruction defence in depth
ten novice learners post instruction defence in depth
four post graduate students in Security Science

All pair-wise comparisons between concepts were coded as dissimilarities, and these data became input for multidimensional scaling analysis as representations of cognitive structure. Although all data were analysed for three dimensions and two dimensions solutions, only two dimensional structures have been presented. However, a limited selection of structures have been presented to enable discussion of the proposed technique.

The Figure 2 shows the 2-D knowledge structure for the novice pre instruction group for Physical Barriers, with the distribution of the facility concepts according to the dissimilarity ratings for this group. The spatial distribution of the concepts represents the knowledge structure, with the dimensions for the configurations undefined at this stage.

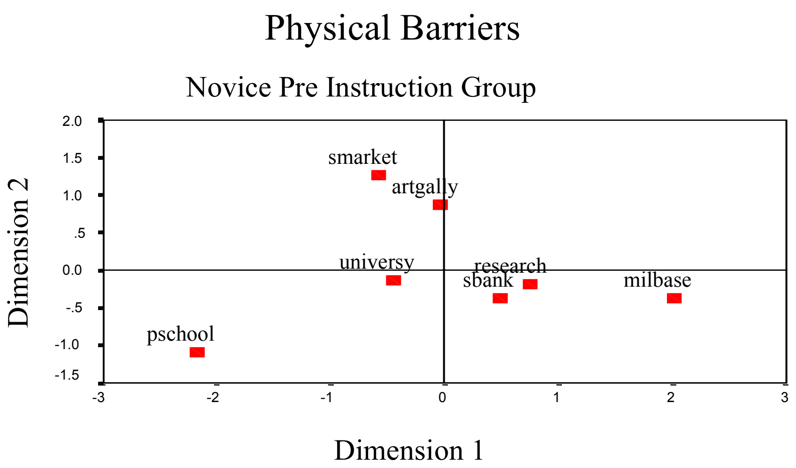

Figure 2: Knowledge structure for Physical Barriers for Novice Pre Instruction Group.

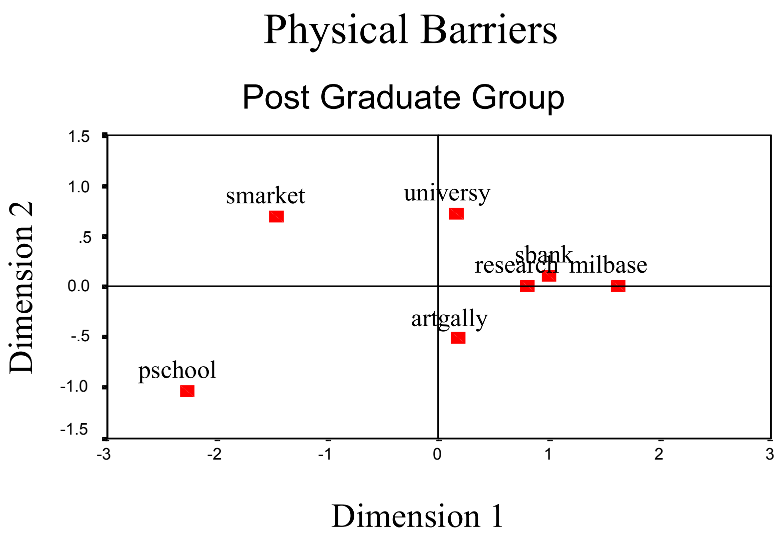

Figure 3: Knowledge structure for Physical Barriers for Post Graduate Group

However, the experts' group knowledge structure represents the formal structure of the content domain (Smith, 1986), and is the structure that novice learners aspire to achieve through understanding of the principle of *defence in depth*. The Figure 3 shows the expert group 2-D knowledge structure for Physical Barriers for the facility concepts. It is expected that this structure approaches that of the ideal configuration.

Although all four types of barriers for the selected facility concepts have been analysed, only knowledge structures for Procedural Barriers for the novice groups, pre and post instruction structures have been compared to the experts structure. The Figure 4 displays the knowledge structure of Procedural Barriers for the novice group before the instructional phase of the project. The relationships of the spatial distribution for the concepts have no reliability as diminished understanding of the concepts are evident as the novices had not studied the knowledge domain.

Following the instructional phase of the project when the learners were presented with the concepts and principles of Defence in Depth, the novice group again responded to the instrument producing dissimilarity data for spatial analysis. The Figure 5 shows the 2-D configuration for the facility concepts for Procedural Barriers in the Defence in Depth strategy.

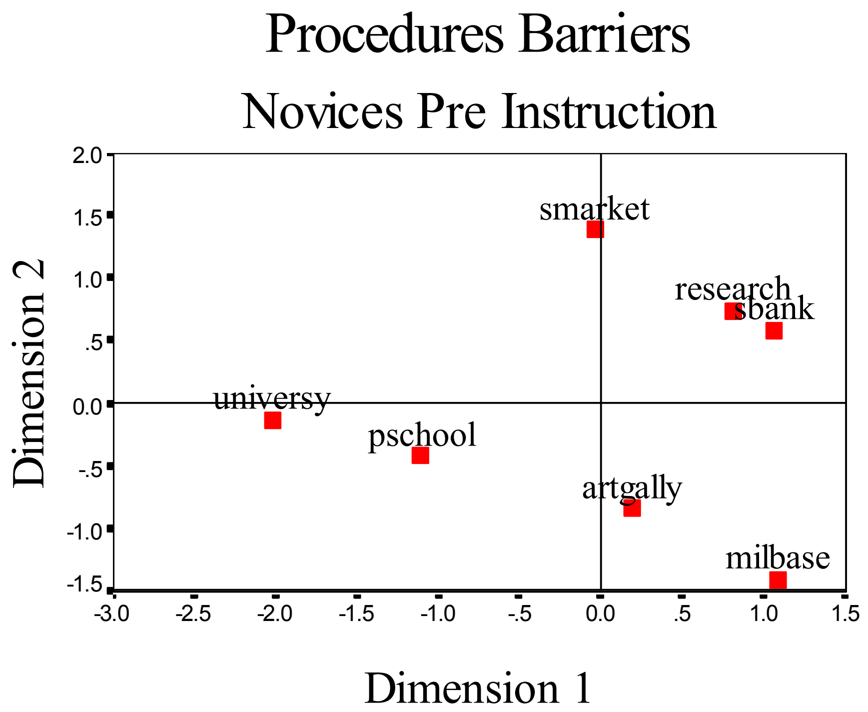

Figure 4: Novice Group knowledge structure for Procedural Barriers before Instruction.

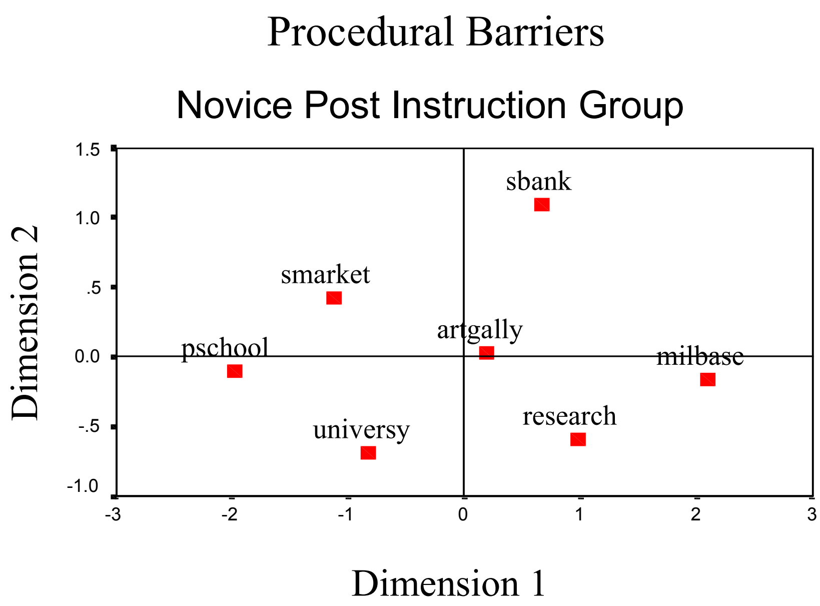

Figure 5: Novice Group knowledge structure for Procedural Barriers after instruction

The MDS statistical technique allows the comparison of knowledge structures through relative weightings on the defined dimensions of the knowledge structures. That is, the strengths of the individual knowledge structures can be displayed on the same dimensions (weighted averages). These weights of individual knowledge structures are represented as vectors in the 2-D conceptual space. The proximity of the knowledge structure vectors is a measure of the similarity of the knowledge structures. The Figure 6 shows the knowledge structure vectors for the Novice Group pre and post instruction for the Procedural Barriers, and the Expert group.

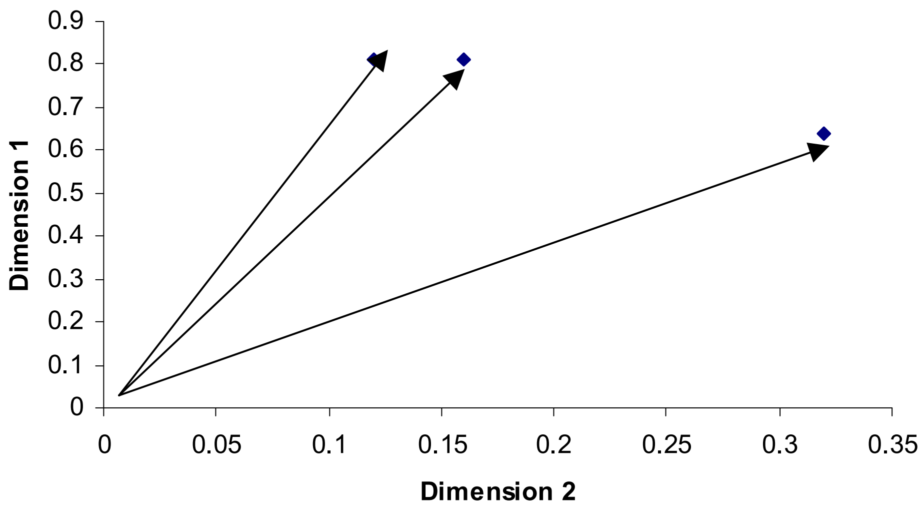

Figure 6: Comparison of the knowledge structures for the Novice Group (pre- and post-) and Expert Group for Procedural Barriers.

The learner-instructor model (Smith, 1986) proposes that the structure of concepts in the knowledge domain become more like the expert with instruction. In the Figure 6, the novice group pre instruction structure for procedural barriers is represented by the left vector according to Dimension 1 and

Dimension 2. Similarly, the central vector represents the novice group post instruction structure. The expert group's structure for procedural barriers is represented by the right vector. The vectors for the pre and post instruction for the novice groups show that the structure becomes more like that of the expert group with instruction.

CONCLUSION

The paper has described a novel approach to the understanding of novice learners in the knowledge domain of the *defence in depth* principle. These knowledge structures of students' perceptions of concepts in a *defence in depth* strategy have been compared to those of the experts in the knowledge domain and can be interpreted as the development of these structures with instruction. The novice learner group has displayed sufficient differences in 2-D knowledge structures to the experts' knowledge structure to claim incomplete understanding by the novices at this stage. However, with appropriate instruction and accumulated maturation of the learners with the *defence in depth* strategy, then it may be expected that these knowledge structures will tend towards the knowledge structure of an expert.

The proposed approach to a better understanding of the *defence in depth* principle by learners is speculative, and rigorous longitudinal studies of the change in knowledge structures for learners in this knowledge domain and other related domains is required to seek validation of the process. Provided that knowledge structures can be shown to be repeatable for individuals, then the reliability of the proposition that the knowledge structures of novice learners and experts will become more alike with suitable instruction is enhanced. The validity of the technique will be tested by further studies into the structure of knowledge of the *defence in depth* principle.

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