Do Problem Solving, Critical Thinking and Creativity Play a Role in Knowledge Management? A Theoretical Mathematics Perspective

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Abstract: Litschka, Markom, Schunder (2006) state that "...a knowledge-based economy requires new approaches in management especially with employee oriented actions, because workability, well-being, and creativity of employees determine the success and sustainability of an organization." Such approaches have to be grounded on established learning theories for life long learning which are conducive to knowledge creation and knowledge acquisition. Situated learning (Lave & Wenger, 1997), constructivism (Piaget, 1971; Vygotsky, 1978), behaviourism (Thorndike, 1915; Skinner, 1958) and cognitivism (Wertheimer, 1912; Kohlberg, 1972; Mezirow, 1962, all cited by Hergenhahn and Olson (1997: 29-48) have dominated education for more than eight decades. Though each theory has made valuable contributions, management of knowledge requires higher order thinking skills such critical thinking, problem solving and creativity on the part of the manager of the organisational knowledge and the part of the knowledge creator. The importance of these three skills, especially for the last two decades, have not only been accepted as important cognitive skills by educators and employers, but they also form part of the critical outcomes in American educational policies (American college personnel association, 1994 cited by King & Baxter-Magolda, 1996) as well as in South Africa (SAQA, 1998; the White Paper on Further Education and Training, 1998: 21-23). What is suggested here is a new approach to knowledge management, the psycho-pragmatic approach, which makes use of theories of learning of mathematics as problem solving, critical thinking and creativity form the essence of knowledge acquisition (Schoenfeld, 1987; Skemp, 1977). Mathematics has been recognised as a subject that enhances higher order skills because on the one hand requires abstract thinking on the other promotes use and application of knowledge (Pushkin 2007; Alonso, 1992; Forinash, 1992). This new approach makes use of psychological learning theories for generation of knowledge and pragmatism for application of such knowledge. It is of cyclic nature as well as of spiral nature based on the idea of Nonaka and Konno (1998) model of knowledge and of Bruner's (1976) spiral curriculum.

Keywords: Knowledge Management, problem solving, critical thinking, creativity, mathematics, psycho-pragmatic

1. Introduction

Moving from an industrial era to a knowledge era, globalisation and technological innovations brought about changes to all facets of life (Halpern, 1997; Pascarella & Terenzini, 1991; Bérubé & Nelson, 1995). People, education, industries and organisations had to adapt in to fast changing world. People started going back to institutions of learning to improve their qualifications and more young people begun to seek higher education. As a result massification of education started to take place. Educational institutions had to upgrade their curricula more often, every two to four years. Back in the 1950s re-curricularisation used to take place every 15 years. Industries begun to make use of modern technologies, and replacing workers as more automation begun to take place. Organisations too started changing their approach to economy. Physical assets, no longer guaranteed their sustainability. So they turned to their intangibles, the human capital, their workers.

Once it was realised by organisations that it was their workers that possessed the necessary knowledge (explicit and tacit or implicit), a shift towards knowledge management became a necessity. Research on knowledge management started shedding light on organisational activities, sustainability and competitive advantage. Litschka, Markom, Schunder (2006) make this very clear when they state that "...a knowledge-based economy requires new approaches in management especially with employee oriented actions, because workability, well-being, and creativity of employees determine the success and sustainability of an organization."

Furthermore, the skills required to perform many simple and complex functions require higher order thinking skills such as, problem solving, critical thinking and creativity among other cognitive skills. These skills have been approached in an isolated way and not in a holistic way. For example from a behaviourist or cognitivistic (or constructivist) (King & Baxter-Magolda, 1996) perspective rather than neocogitivist (a combination of the two perspectives, Bandura, 1978) or pragmatic perspective

(Dewey, 1909; Schaffler, 1999). It will be shown that a new paradigm, the psycho-pragmatic approach, is a holistic approach, which takes into account the psychological as well as the pragmatic way can make a better contribution to learning. It has been established that mathematics, due to its nature, enhances cognitive skills such as problem solving, critical thinking and creativity. This paper aims then at offering an alternative way to acquisition, creation and dissemination of knowledge, the three pillars of knowledge management.

2. Problem statement

Problem solving, critical thinking and creativity have been recognised as three cognitive skills that may contribute to better decision making, judgement, evaluation of situations and information, open-mindedness and so on. Mathematics, on the other hand, by its nature is an abstract subject which requires higher thinking skills, and it is paradoxically used to solve complex world problems. John's Polkinghome (1930-) describes this very accurately when he says that mathematics is the abstract key which turns the lock of the physical universe. It can be hypothesised then that it can make a contribution to the development or enhancement of these three cognitive skills. Since mathematics is context free these skills can be transferred to any other context. One such context is the organisation, creation and application of knowledge in decision making which are the core processes in knowledge management. The questions to be answered then are:

Do problem solving, critical thinking and creativity play a role in knowledge management?

and

How does mathematics affects the acquisition of these three cognitive skills?

To answer these questions it is necessary to answer the following sub questions:

- What is problem solving, critical thinking and creativity?
- Is there a relationship between these three cognitive skills and knowledge management?
- What is the role of mathematics in developing or enhancing the three cognitive skills?

In the end, a new paradigm will be developed which aims at developing a better understanding of how knowledge is acquired and created.

3. Problem solving, critical thinking and creativity

Problem solving, critical thinking and creativity are three constructs that have become very prominent especially in the last decade due to a number of reasons: the move from an industrial era to a knowledge era; globalisation; complexity in management systems; and technological innovations, to name just a few (Halpern, 1997; Pascarella & Terenzini, 1991; Bérubé & Nelson, 1995). The importance of these three cognitive skills for knowledge creation, and application to harness the complex world is stressed by the National Education Goals Panel (1991), the American college personnel association (1994 cited by King & Baxter-Magolda, 1996) and a number of authors (Vaughn, 2008; Pushkin, 2007; Williams, 2005; Halpern, 1997; Pascarella & Terenzini, 1991). In South Africa these skills also form three of the seven critical outcomes of education (SAQA, 1998; the White Paper on Further Education and Training, 1998: 21-23).

However, problem solving, creativity and critical thinking skills are complex and closely inter-related and thus difficult to define (Pushkin, 2007; Halpern, 1997; Van den Berg, 2000; McPeck, 1990; Lombard & Grosser, 2004; Brown, 1998). There is no agreement among many authors whether either one of them is the product of the other. They are seen as being complementary (Martinez, 2007).

For this study, working definitions for these three constructs have been created in order to facilitate the theoretical framework: Problem solving is an activity that makes use of cognitive or cognitive and physical means to overcome an obstacle (problem) and develop a better idea of the world that surrounds us. It was the mathematician Polya (1973: 15) a pioneer in problem solving who wrote: ' [s]olving a problem means finding a way out of a difficulty, a way around an obstacle, attaining an aim that was not immediately understandable.

Problem solving is a complex activity (Green & Gillhooly, 2005: 347; Halpern, 1997: 219) and it takes place over time like all other skills, and the various cognitive processes and mental representations interact in certain ways. It often involves attention, memory, reasoning, judgement and decision making (Matlin, 2005: 365). Problems can be well structured or ill-structured, complex. Some share the same characteristics (isomorphic) others are difficult to represent or to model them in our minds and find a solution for them. But a problem, depending on its nature can have different solutions but some could be more effective or efficient than others. The problem solver must be able to see all the alternative solutions and decide which is the best. This requires critical thinking.

For this study, critical thinking is an ability or skill by which the person transcends his subjective self in a wilful manner in order to arrive rationally at conclusions (not necessarily favourable to him or her) that can be substantiated using valid information. Critical thinking (CT) is considered to be a higher order type of thinking, non algorithmic, complex mode of thinking that often generates multiple solutions (Barak, Ben-Chain & Zoller, 2007). Using Bloom's taxonomy the lower levels could be considered to be low order thinking skills while higher levels such as analysis, synthesis and evaluation higher order thinking skills (Barak et al, 2007). These skills combined give rise to other skills such as problem solving, inferring, estimating, predicting, generalising, and creative thinking (Wilks, 1995 in Barak et al, 2007). If a person's thinking can vary from a very simple and mundane thought to a very sophisticated and complex one then the same can be said about CT, a particular and complex way of thinking; and CT is a human activity which involves "much more than skills and logical analysis" (Brookfield, 1987: 1). Pushkin (2007) and others (e.g. Alonso, 1992; Forinash, 1992 cited by Pushkin, 2007) found that CT is connected to mathematics, scientific problem solving, and physical sciences among other fields. Ultimately what CT leads you to is knowledge, understanding and empowerment (Vaughn, 2008).

Halpern (1997) defines creativity as a set of processes such as novel problem solving, generating and evaluating possible solutions, and judging how uniquely and how well a problem is solved; and mathematics is about problem solving, critical thinking and creativity. Creativity, like problem solving and critical thinking, involves mostly sub-conscious cognitive actions which at times surprise even the person who performs that action. Very often we see people producing unexpected results, unique solutions to problems, being innovative and so on. Their actions are unusual and appropriate (Halpern, 1997: 243; Matlin, 2005: 391) and both require judgment: How unusual the action was and how well did it meet certain criteria? Halpern (1997: 243) argues since answering these questions involve judgement then creativity exists in the eyes of the observer. Someone has to judge the idea or act as useful , unusual and good, before its can be labelled as creative and therefore there will always be disagreement on the way these attributes are judged.

The authors here accept the research findings about problem solving, creativity and critical thinking. However, the authors view the difficulty in not reaching consensus about these constructs lies on the fact that they are treated separately. Throughout the paper the three constructs will be treated as a unity. They can be conceived as the three vertices of a triangle as shown in figure 1. It is hypothesised that the situation will dictate which construct predominates and affects the others. For example it is possible that though creative thinking to discover a new theory. This theory needs to be critically analysed. The various problems that arise need to be solved. Another case could be that a problem is encountered and there could be many solutions. A unique way could be discovered which could solve the problem, by doing a critical analysis. What can not be disputed is that problem solving, critical thinking and creativity play a central role in solving complex situations.

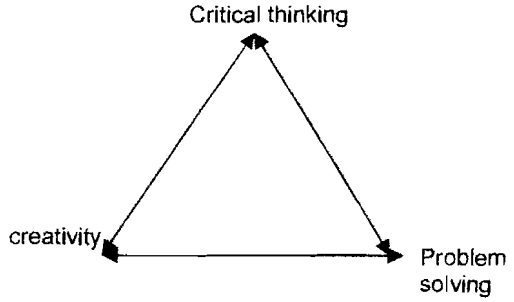


Figure 1: The unity of higher order cognitive skills

4. Knowledge management and cognitive skills

'Knowledge' is a complex concept and there is a tendency to be confused with 'information.'. Very often information is "confused" with knowledge and as a result knowledge and information tend to be used interchangeably (Peters, 2002 in Wenzel, 2007). Knowledge involves understanding of information. When information makes sense to somebody and uses it to solve certain problems then it becomes knowledge (Barclay & Murrray, 1997). And "[k]nowledge management is not really about managing knowledge, but rather managing and creating a corporate culture that facilitates and encourages the sharing, appropriate utilization, and creation of knowledge that enables a corporate strategic competitive advantage." (Walczak, 2005) Acquisition of knowledge though is a long process. Jonassen (1992) suggested three stages of knowledge acquisition: the introductory, advanced, and expert (see Figure 2)

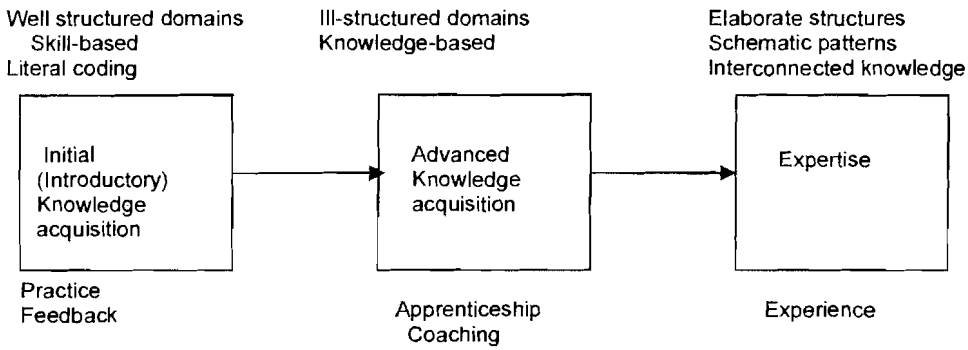


Figure 2: Three stages of knowledge acquisition (Jonassen, 1992: 142)

In the introductory stage, the learners have very little directly transferable prior knowledge about a skill or content area. The second phase of knowledge construction is the advanced knowledge acquisition where the learner acts as an apprentice and is able to solve more complex problems, domain or context dependent. Expertise is the last phase whereby the learner has acquired more rich interconnected knowledge structures. Constructivistic learning environments are most appropriate for advanced knowledge acquisition as experts need very little instructional support (Jonassen, 1992). Acquired knowledge (general and domain specific) and cognitive skills are employed by the individual to organise, create, share and disseminate knowledge, the pillars of knowledge management. But there are different types of knowledge. Many authors agree with the classification of knowledge into at least procedural, and conceptual (publicly accessible) (Flavell, 1976; Smolesky, 1988 cited in Sun, 2002; Alonso, 1992; Forinach, 1996) while Anderson and Krathwohl (2001) also distinguished factual and meta-cognitive. Shavelson, Ruiz-Primo and Wiley (2005) also classified knowledge into declarative knowledge that includes conceptual knowledge other than facts, procedural knowledge, strategic knowledge and add schematic knowledge – "knowing why"- to the other types of knowledge. The authors also add another dimension to these types of knowledge (the length of knowledge), and that is the "depth" which deals with proficiency and that is the extent, structure and others. These types of knowledge are affected by emotions and motivation. In Table 1 they give a conceptual framework of the two dimensions.

Table 1: Conceptual framework of knowledge (Shavelson et al, 2005: 415)

Proficiency → Low high	**Declarative Knowledge**	**Procedural Knowledge**	**Schematic Knowledge**	**Strategic Knowledge**
	Knowing "that"	Knowing "how"	Knowing "why"	Knowing "where, when and how"
Extent (how much?)	Domain-specific content:	Production rules/ sequences	Principles/ schemes/ Mental models	Strategies/ domain-specific heuristics
Structures (how is it organised)	Facts Definitions descriptions			
Others (How efficient? How precise? How automatic?)				

Table 1 shows the different types of knowledge and the second dimension which has to do with proficiency in the various types of knowledge. This means that although learners might possess the different types of knowledge they can differ on the extent to which such particular type of knowledge has been acquired, how well organised is in the cognitive structure so that retrieval is automatic and how accurate and efficient it is. Classifying knowledge into these types can assist knowledge managers to identify the various knowledge workers who are specialists in a particular type(s) and derive the maximum output from them.

5. Mathematics and cognitive skills

Mathematical concepts are abstract right from the word go. For example the numbers are abstract if not referred to something else: 2 apples, 5 persons and so on. What makes the learning of mathematics even more difficult is that the direction of learning is towards more abstract concepts (Skemp, 1977; Schoenfeld, 1987). Clement and Julie (2004) in fact state that the development of abstract thinking goes hand in hand with the child's developing mathematical skills. Abstract thinking involves high order thinking skills, such as problem solving, critical thinking and creativity.

Learning of mathematical concepts involves active engagement of the learner in cognitive activities such as problem solving, reasoning, making connections, creating representations, and communicating. Concepts are the basis of thinking, and concepts are expressed in words that derive their meaning from the way they are used in specific language games (Renzl, 2007).

Mathematics exhibits all different types of knowledge as discussed earlier. For example, using Shavelson's et al (2005: 415) classification, even the simplest mathematical problem contains all types of knowledge. In a simple addition problem, one must decide "why" (schematic), "what and how" (strategic) also. Therefore, the learning of mathematics can be used for the acquisition and application of knowledge. The processes involved in solving a mathematical problem are analogous to those used to solve other world problems

Since mathematics is a subject that is also based on logic and one has to make sense of concrete as well as abstract problems then it can be argued that it can enhance critical thinking skills where logic is one of its components. And Pushkin (2007), White (1993), and others (e.g. Alonso, 1992; Forinash, 1992 cited by Pushkin, 2007) found that critical thinking is connected to mathematics, scientific problem solving, and physical sciences among other fields as stated earlier.

It is clear that the learning of mathematics involves a number of complex cognitive processes which form the cornerstone of specific and general knowledge acquisition. However, acquisition of the different types of knowledge requires an approach that that combines the psychology of learning and the act of doing. This approach can be called the psycho-pragmatic approach which is illustrated by 'The act of learning' (see Appendix A).

6. The psycho-pragmatic approach

This learning approach hinges on the psychological aspect, thinking, and the pragmatic aspect of doing, experiencing, practicing various products of thinking which require certain skills, such as physical or mental, which help the individual solve problems (see Appendix A). Thinking can be concrete (low level of thinking) or abstract (high level of thinking) though there is no thought that is purely concrete or abstract (Resnick, 1989). Through abstraction (physical or reflective, Clements & Julie, 2004; Skemp, 1977) the various concepts (primary and secondary) begin to form, by conceptualizing and establishing relationships which give rise to principles, and a cognitive structure is built. As assimilation and accommodation (Piaget, 1971) of the new concepts is taking place in the cognitive structure and structures of knowledge are formed, the person develops the necessary skills and attitudes to lead a meaningful life. Acquired knowledge is domain specific (specializing in something) as well as general (making it possible to communicate with others).

Using the acquired knowledge and skills the person is capable of solving problems. But problems can vary from simple structured problems to complex and unstructured problems. Structured problems are often found in school situation but not in the real world where most of them are unstructured. Although it is not easy to duplicate reality in a classroom situation, what is suggested here is that utility of what is learned and justification of why it is necessary to learn a particular concept is necessary as knowledge is validated by its usefulness. This is the core idea of pragmatism, the "doing" of "the act of learning".

Pragmatism

The pragmatic view stresses the experimental character of the empirical science, emphasising the active phases of the experimentation. Learning, logically, truths that appear self-evident or common sense is not enough. Hypotheses can be formed by thinking of the practical problem and predictions can be made. The results could prove or nullify our hypotheses. It promotes an inquiring mind with respect to physical laws. "Inquiry itself is action, but action regulated by logic, sparked by theory, and issuing answers to motivating problems of practice" (Schaffler, 1999: 4). Learning from experiences is an active process.

According to pragmatism knowledge is validated by its usefulness: What can we do with it? John Dewey emphasised motivation in education where " if nobody inspires you to learn the chances are that you will not learn well." (Sternberg & Ben-Zeev, 2001: 24). Dewey also emphasised the practicality of education. To learn effectively one must see the point in education-the practical use of it.

However of late it has been realised that complex human phenomena can not be understood from a single perspective such as behaviouristic, cognitivistic or constructivistic perspectives. It is necessary to approach reality from a holistic perspective which does not reject other perspectives but places equal importance to the inner self of the human being as well as the outer reality and their relationship. If this is true, then approaching learning from a psychological as well as pragmatic way could lead to better understanding of reality.

Johnson and Onwuegbuzie (2004) give the general characteristics of pragmatism as they view it. The most important characteristics of pragmatism which are directly related to knowledge acquisition and creation are: the recognition of using a holistic approach taking into account the inner self and outer reality; the role of constructivism and realism, the experiential, with respect to knowledge acquisition; Using a holistic approach for gaining understanding of people and the world; Pragmatism promotes praxis, a human inquiry which assists the individual to try out things that work, solve problems and provides us with the best answers. Finally, pragmatism highlights the dynamicism of knowledge; Knowledge is tentative and needs renewal.

The acquisition and usage of knowledge using the psycho-pragmatic approach, it requires the problem solver to be able to conceptualise and think critically and creatively. The required thinking level will depend on the type of problem and the solution will depend on the level of cognitive development of the problem solver (Green & Gilhooly, 2005: 347). That is, the more complex the problem is the higher the level of thinking will be required.

The act of learning process accommodates such mixed theory of learning on the basis that it is not only cyclical where it starts with the encounter of a new concept (input) and ends with knowledge of the concept (output) at a low level. But it also follows a spiral way where the concept is acquired on a higher level (level 2) (see Appendix B). This is similar to the idea of Nonaka and Konno (1998) model of knowledge and of Bruner's (1976) spiral curriculum. But it is also equivalent to Shavelson et al (2005: 415) second dimension, depth of knowledge.

Mathematics as stated earlier is a subject whereby problem solving, critical thinking and creativity form the essence of knowledge acquisition (Schoenfeld, 1987; Skemp, 1977; Long, 2005). Initially abstract (or implicit) ideas become 'concrete' when related to reality. For example, the numbers are abstract but when related to quantity become concrete. Mathematical knowledge is acquired in a horizontal (say, cycle 1) of the act of learning as well as vertical (say level 1). Then cycle 2 follows and knowledge is acquired in level 2 and so on. This way higher thinking levels are achieved (see appendix B). The processes that are involved in every cycle of learning are the same (Skemp, 1977; Schoenfeld, 1987) but every time a cycle is completed a higher level is achieved.

7. Discussion

If knowledge management is viewed briefly as a process of creating, capturing, and using knowledge to enhance organizational performance, then every organization should aim at achieving such objectives. Each of these objectives demands certain knowledge and skills which should have been acquired before. Therefore acquisition of certain knowledge and skills is a prerequisite of achieving these objectives. "The act of learning" illustrates such acquisition. The approach being used, the

psycho-pragmatic approach, combines the psychological (inner cognitive functions) and the effective use of knowledge (outer function).

Three of the most important cognitive skills in knowledge creation are problem solving, critical thinking and creativity. Research is inconclusive as to whether any of them is a product of the other or part of another (Papastephanou & Angeli, 2007; Martinez, 2007; Sternberg, 1986; Leader & Middleton, 2004). The above exploration to these constructs points to the fact that there is an interdependency among them and the situation dictates which one is the predominant one in a specific situation. Representing them as the vertices of an equiangular triangle, it assists us to see the interconnectivity between them. If we emphasise the one at the expense of the other the structure collapses. Treating them on equal terms assists us in maximizing their usage.

There is still no agreement among researchers that these skills can be taught. For example Brookfield (1987) insists that there is no standard approach to facilitate CT while others, Barrows (1986), Tiwari et al.(2006), Bensley (1993), and Sternberg and Ben-Zeev (2001) maintain it is possible through the use of specific strategies and problem-based- learning (PBL) is one such a strategy. But there is agreement that they can be enhanced. Pascarella (1999), Feldman and Newcomb (1969) (in Gellin, 2003) found overall attending college that improve CT skills. Brüssow (2005) cites Bailin (1987) who maintains that CT can be taught through inventive instruction and through open-ended problems having learners being actively involved. Welsh and Paul (1988) speak of improvement of CT which implies that the individual does posses some CT skills and they can be improved (cited by Lombard & Grosser, 2004). Angelo (1995, cited by Lombard & Grosser, 2004) disagrees. He argues that CT does not develop as a result of maturation, but involves skills which are notoriously difficult to teach and learn. With respect to effect of instructional techniques on CT Tsui (1999) found these studies yielded inconsistent results. Either instruction had a positive effect or no effect.

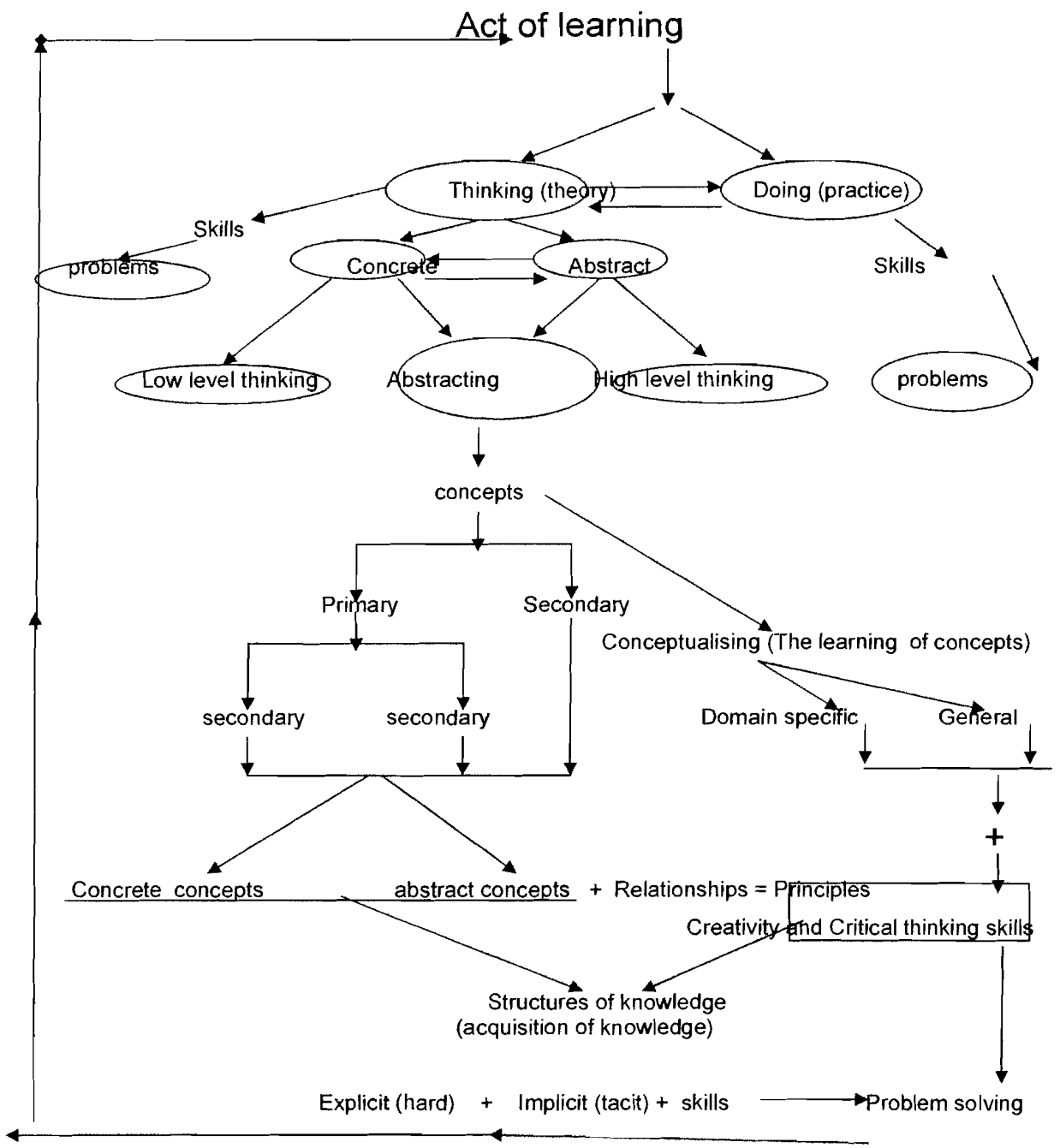
The learning of mathematics can be used as a model for the acquisition of knowledge and skills in a horizontal (different types of knowledge) as well as vertical (insight, organization, efficiency) way. Since knowledge is the core common prerequisite in problem solving, critical thinking and creativity, and mathematics is a subject that develops and enhances these constructs, then it can be argued that these constructs play a pivotal role in knowledge management.

Mathematics involves abstract thinking, a prerequisite to the learning of mathematical concepts. To solve mathematical problems it is necessary to possess high order thinking skills. Such skills can be developed through application of mathematical knowledge into real life situations. This way the newly acquired knowledge and skills are combined with existing knowledge and skills to create new knowledge and higher order thinking skills such as critical thinking and creativity. The mechanism of such acquisition can be explained by the psycho-pragmatic approach to learning. This approach, because it is based on the psychology of learning in view of applying the acquired knowledge and not create knowledge for the sake of it, can make a real contribution to knowledge management. Knowledge workers and knowledge managers are continuously faced with real situations and have to make informed decisions. Thinking critically, and being innovative and creative leads to sustainability and creating a competitive advantage for an organisation.

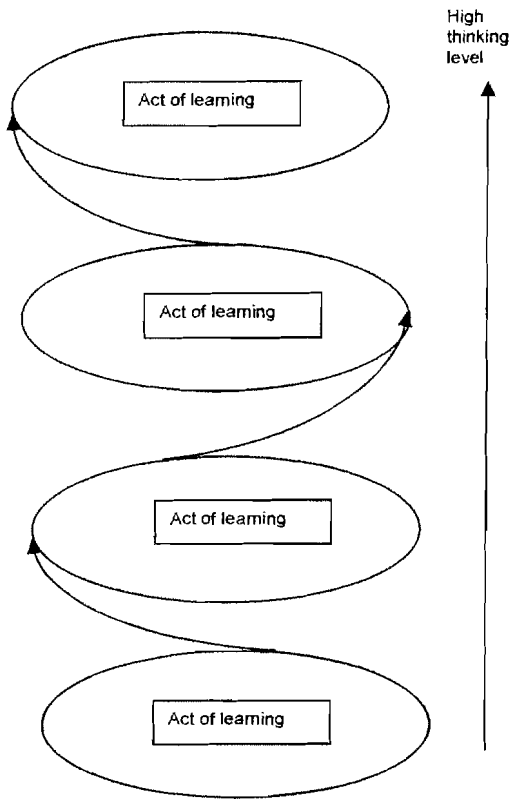
8. Conclusion

Problem solving, critical thinking and creativity, are three higher order cognitive skills which are used for the creation and application of knowledge in real life situations. These skills are necessary to harness the ever changing knowledge economy and create a competitive advantage due to the fact that they exist in the minds of people and can not be captured in any form. It is the person's choice to share such skills. Approaching the development and enhancement of such skills from a psycho-pragmatic perspective it leads to better management of knowledge in an organisation since this approach is grounded on sound psychological theories of knowledge acquisition and application of such knowledge in an effective way which leads to a competitive advantage. Mathematics by its nature, develops and enhances higher order thinking skills and thus in a direct as well as indirect way can improve the creation of knowledge in an organisation.

9. Appendix A


Act of learning
Thinking (theory)
Doing (practice)
Skills
problems
Concrete
Abstract
Skills
Low level thinking
Abstracting
High level thinking
problems
concepts
Primary
Secondary
Conceptualising (The learning of concepts)
secondary
secondary
Domain specific
General
+
Concrete concepts
abstract concepts
+ Relationships = Principles
Creativity and Critical thinking skills
Structures of knowledge
(acquisition of knowledge)
Explicit (hard) + Implicit (tacit) + skills
Problem solving

10. Appendix B



References

Alonso, M. 1992. Problem solving and conceptual understanding. *American Journal of Physics,* 60, pp 777-778.
Anderson, L.W., & Krathwohl, D.R. (eds). 2001. A taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy of educational objectives. New York: Longman.
Astin, A.W. (1993). What matters in college? Four critical years revisited. San Francisco: Jossey-Bass Inc.
Barclay, R.O., & Murray, P.C. 1997. What is knowledge management? Available from: http://www.knowledge praxis/what is knowledge mabagement.htm. (Accessed 20 April 2008).
Barrows, H.S. 1986. A taxonomy of problem-based learning methods. *Med Educ* 20(1), 481-486.
Bensley, D.A. 1993. Critical thinking in psychology: A unified skills approach. Brooks/Cole publishing company.CA.
Bérubé, M., & Nelson, C. 1995. Higher education under fire: politics, economics, and the crisis of the humanities. New York: Routledge.
Bloom, B.S. 1979. Taxonomy of educational objectives. Book 1. New York. McGraw-Hill, inc.
Brookfield, S.D. 1987. Developing critical thinkers: Challenging adults to explore alternative ways of thinking and acting. Open University press. England.
Brown, K. 1998. Education, culture, and critical thinking. Sufolk, The Book Company.
Bruner, J. 1976. Studies in cognitive growth. New York: Wiley, J & sons inc.
Brüssow, S.M. 2005. Concept mapping: An invitation to creative thought. *Journal of college student development*, 43 (1), pp 284-292.
Clement, D.H., & Julie, S. 2004. Thinking big. *Scholastic parent & child*, 11(5), April/May.
Department of Education, 1997. White paper on higher education. *Government gazette.* Pretoria. Government printer No 17944/1997.
Forinash, K. 1992. What are we trying to do in our introductory course? *American Journal of Physics,* 60, pp 11-12.
Gellin, A. 2003. The effect of undergraduate student involvement on critical thinking: A meta-analysis of literature 1991-2000. *Journal of college student development*, 44 (6), pp 746-762.
Green, A.J.K & Gillhooly, K. 2005. Problem solving. ***In*** Braisby, N. and Gelatly, A. (Eds). Cognitive Psychology. Oxford University Press. Oxford.

Halpern, D.F. 1997. Critical thinking across the curriculum: A brief edition of thought and knowledge. Lawrence Erlbaum associates. London.

Hergenhahn, M.H., & Olson, B.R. 1997. An introduction to theories of learning. New York: Prentice Hall.

Jonassen, D.H. 1992. Evaluating constructivistic learning. *In* T.M. Duffy & D.H. Jonassen. (Eds). 1992. Constructivism and the technology of instruction: a conversation. New Jersey: Lawrence Erlbaum Associates.

Johnson, R.B., & Onwuegbuzie, A.J. 2004. Mixed methods research: A research paradigm whose time has come. *Educational Researcher, 33(7).*

King, P.M, & Baxter-Magolda, M.B. 1996. A developmental perspective on learning. *Journal of college student development*, 37(2), pp 163-173.

Kwon,O.N., Allen, K., & Rasmussen, C. 2005. Students' retention of mathematical knowledge and skills in differential equations. *School science and mathematics,* 105(5), pp 227-240.

Lave, J. & Wenger, E. 1991. Situated learning: Legitimate peripheral participation. Cambridge: Cambridge university press.

Leader, L.F., & Middleton, J.A. 2004. Promotong CT dispositions by using problem solving in middle school mathematics. *Research in middle level education online.* 28(1).

Lipman, M. 1982. Philosophy for children. *Thinking: The Journal for philosophy for children,* 3, p 37-47.

Litschka, M., Markom, A. & Schunder, S. 2006. Measuring and analyzing intellectual assets: an integrative approach. *Journal of intellectual capital,* 7 (2): 160-173.

Lombard, B.J.J., and Grosser, M.M. 2004. Critical thinking abilities among prospective educator: ideals versus realities. *South African Journal of Education, 24(3),* pp 212-216.

Long, C. 2005. Maths concepts in teaching: Procedural and conceptual knowledge. *Pythagoras*: 62, pp 59-65.

Martinez, M.E. 2007. What is metacognition? Phi Delta Kappan. *Bloomington*, 87(9). pp 696-700.

Matlin, M.W. 2005. Cognition. New Jersey: John Wiley & sons.

McCormick, R. and Paechter, C. 1999. Learning and knowledge. London: Paul Chapman Publishing Ltd.

McPeck, J.E. 1990. Teaching critical thinking. New York: Routlege, Chapman & Hall, Inc.

National education goals panel. 1991. Executive summary: The National Education Goals Report, 1991: Building a nation of learners. Washington, DC: National Education Goals Pane.

Nonaka. I., & Konno, N. 1998. he concept of 'Ba': Building a foundation for knowledge creation. *Californian Management review, 40(3), 40-54.*

Papastephanou. M., & Angeli, C. 2007. Critical thinking beyond skill. *Educational philosophy and theory*, 39(6), pp 604-621.

Pascarella, E. T. 1999. The development of critical thinking: Does college make a difference? *Journal of college student development*, 40(5), pp 562-569.

Pascarella, E.T., & Terenzini, P. 1991. How college affects students. San Francisco: Jossey-Bass.

Piaget, J. 1971. Science of education and the psychology of the child. New York: The Viking press.

Polya, G. 1973. How I solve it: Anew aspect of mathematical method. New Jersey: Princeton university press.

Pushkin, D. 2007. Critical thinking and problem solving-the theory behind flexible thinking and skills development. *Journal of science education,* 8(1), pp 13-19.

Renzl, B. 2007. Language as a vehicle of knowing: the role of language and meaning constructing knowledge. *Knowledge management research and practice.* 5. pp 44-53.

Resnick, L.B. 1989. Education and learning to think. Washington D.C: National academic press.

Scheffler, I. 1999. Epistemology and education. *In* R, McCormick & C. Paechter, C. 1999. Learning and knowledge. London: Paul Chapman Publishing Ltd.

Schoenfeld, A.M. (ed). 1987. Cognitive science and mathematics education. New Jersey: Erlbaum.

Shavelson, R.J., Ruiz-Primo, M. A., & Wiley, E.W. 2005. Windows into the wind. *Higher Education*, 49, pp 413-430.

Skemp, R.R. 1977. The psychology of learning mathematics. London: Routledge & Kegan Paul.

South African Qualifications Authority (SAQA). 1998. Regulations under the South African Qualifications Act,1995. (Act No. 58 of 1995). Government Gazette No 6140. Vol 393 No 18787, 28 March 1998, Pretoria: South Africa.

Steiner, G. 2006. How appropriate are two established concepts from higher education for solving complex real-world problems? A comparison of the Harvard and the ETH case study approach. *International journal of sustainability in Higher education.7(3), p322-340.*

Stenberg, R. (Ed). 1985. Human abilities: An information processing approach. New York: Freeman and Company.

Sternberg, R.J. 1986. Teaching critical thinking, part 1: Are we making critical mistakes? *Phi delta kappan,* pp 194-198.

Sternberg, R.J. & Ben-Zeev, T. 2001. Complex cognition: The psychology of human thought. Oxford University Press. Oxford.

Sun, R. 2002. Duality of the mind. New Jersey: Lawrence Erlbaum associates.

Tiwari,a., Lai,P., So,M. & Yuen, K. 2006. A comparison of the effects of problem-based learning and lecturing on the development of students' critical thinking. *Med Edduc,41(2), 156-174.*

Tsui, L. 1999. Courses and instruction affecting CT. *Research in higher education.* 40(2).

Van den Berg, M.E.S. 2000. Is there a need for critical thinking skills' modules at tertiary level? *South African Journal of Higher Education*, 14(1), pp 96-107.

Vaughn, L. 2008. The power of critical thinking: Effective reasoning about ordinary and extraordinary claims. Oxford University Press. N.Y.

Vygotsky, L.S. 1978a. Thought and language. MIT press and John Wiley. N.Y.

Walczak, S. 2005. Organisational knowledge management structure. *The learning organisation,* 12(425005), 330-339

Walsh, C.M., & Seldomridge, L.A. 2006. Critical thinking: Back to square one. *Journal of nursing education,* 45(6), pp 212-221..

Williams, S.W. 2002. Making better business decisions: Understanding and improving critical skills and problem solving. Sage publications, USA