Complex Thinking in a Project-Based Classroom

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Abstract

Present instructional methodology in the information system design (ISD) environment is in need of explicit guidelines for promoting the thinking skills of learners, thus failing to fully develop their technological problem solving skills in general. Shelly, Cashman and Rosenblatt (2001) point out that system design tasks demand critical thinking while Harris (1999:61) highlights abstraction skills. Complex thinking and strategies to facilitate thinking skills have not been sufficiently investigated in the project-based classrooms.

The aim of this paper is to explore complex thinking and the strategies for facilitating complex thinking of learners applicable to a project-based classroom.

The nature of this research required an in-depth literature review where different conceptions, programmes and models of thinking processes were analysed forming the source for compiling criteria for an instructional web design programme (IWDP). The integration of the literature findings reveals a variety of instructional strategies which should be considered in enhancing cognitive skills and creating a meaningful learning atmosphere. Different perspectives on complex thinking reveal the integrated nature of thinking where collaborative effort in a project-based classroom, learners' reflective skills and a variety of explicitly planned context-based strategies were considered for building a framework for the IWDP.

INTRODUCTION

In the relevant literature there is a remarkable absence of discussion on the identification and explicit facilitation of a wide range of thinking skills that learners should develop during information system design (ISD). Different ideas on problem-based learning (Duffy & Cunningham, 1997) and metacognition (Johnson, 1997:161-180; Fogarty & McTighe, 1993:165) are not sufficiently incorporated in present project-based classrooms, ignoring constructivist principles of learning and teaching (Winn, 1990:55; Magadla, 1996:83). Complex thinking includes “goal-directed, multi-step strategic processes, such as designing, decision making and problem solving and this is an essential core of higher order thinking” (Iowa Department of Education, 1989:7; cited by Jonassen, 1996:27-29).

There are a number of research findings that point to the integrated nature of thinking processes (Beyer, 1991; Mebl, 1997; Johnson, 1997; Ankiewicz, De Swardt & Stark, 2000). However, it is not clear how these thinking processes could be integrated through current instructional strategies. There is a shortage of strategies that support the development of procedural knowledge during problem solving (McCormick, 1997:152).

The experience of the researcher in this study confirms that the present instructional strategies in project-based classrooms are still not suitable for the development of the thinking skills of learners because they do not raise the learners’ awareness of the importance of reflecting on thinking processes while exploring a variety of design solutions in an ISD context. The researcher of this study organised a project-based classroom in a well equipped computer centre at a university and presented the IWDP in order to teach learners web design and to facilitate complex thinking (Jakovljevic, 2002). In the project-based classroom participants were divided into five groups following the Jigsaw II Model of co-operative learning. Jigsaw II is a form of co-operative learning in which individual learners become experts on subsections of a topic and teach those subsections to others. Task specialisation requires that different learners assume specialised roles in reaching the goals of a learning activity (Eggen & Kauchak, 1996: 286; Blignaut, 1993: 23). Learners worked on a real-world project that consisted of a car purchasing scheme.

This paper reports on an investigation of complex thinking as an essential pillar in setting the theoretical framework for the development of the instructional web design programme (IWDP). An IWDP was developed with the purpose to guide learners towards efficient technological problem solving during web page design (Jakovljevic, 2002).

The key question addressed in this paper is: *What are appropriate strategies for the development of complex thinking in a project-based classroom?* In considering this question, we argue the need for relevant thinking skills, instructional features and strategies for improving complex thinking as a critical learning outcome for school learners (South African Qualification Authority, 1997). It is assumed that the identification and analysis of appropriate thinking skills and strategies will engage learners in design activities.

A BASIS FOR CREATING THE FRAMEWORK FOR THE IWDP

Major theoretical perspectives underlying the development of the IWDP

The development of the IWDP was based on the constructivist theoretical perspective (Dick, 1991; Magadla, 1996; Duffy & Cunnigham, 1997) encouraging activity-based practice necessary for an ISD context. The constructivist approach focuses on knowledge construction and the development of reflective awareness of learning processes. Constructivists emphasise that learners need to be actively involved, to reflect on learning and to make inferences (McCormick,1997:141; Winn,1990:53). Constructivist classrooms provide the freedom for learners to find alternative solutions and to reflect on learning (Zietsman, 1996). Criteria within the essential pillar on complex thinking are based on the constructivism as a major theoretical perspective forming a unified approach for the development of the IWDP.

A variety of conceptions, models and programme, which illustrate thinking processes, is the topic of further analysis.

Conceptions, Models and Programmes on Complex Thinking

Numerous definitions of thinking exist in the literature. The logical thinking processes are usually linked to insight, conceptual creativity, imagination and intuition, which are essential components of discovery (Walters, 1990:450). There appears to be no common interpretation relationg to the composition of thinking processes on higher levels amongst authors discussion on thinking (Resnick 1987; cited by Greeno, 1989:135; Marzano, Brandt, Hughes, Jones, Presseisen, Rankin and Suthor, 1988; cited by Johnson, 1997:162-163; Fogarty & McTighe, 1993:167; Walters, 1990; cited by Jonassen, 1996:26).

The development of the IWDP was based on an in-depth investigation of the processes of complex thinking. Although the concept of complex thinking is mentioned in research findings (Iowa Department of Education, 1989:7) the incorporation of the main thinking processes under this concept vary among different authors. According to them "…complex thinking includes goal-directed, multi-step strategic processes, such as designing, decision making and problem solving and this is an essential core of higher-order thinking" (Jonassen, 1996:27-29). Higher-order thinking consists of critical, creative and complex thinking, which entails problem solving, decision making and designing (Jonassen, 1996:33). Eggen and Kauchak (1996:17) present models of higher-order thinking that only highlight critical thinking.

The researcher of this study is of the opinion that there is a need for employing an inclusive term referring to higher order thinking. Such an inclusive term can lead to a better understanding of the thinking processes in the ISD context. One term could replace the expressions which separate critical and creative processes from complex thinking. The term proposed for the purpose of this study is 'complex thinking', as an umbrella concept under which all other processes of higher-level thinking belong.

There are many existing programmes, models and conceptions of thinking, which can be used to teach learners to think critically, and to solve problems in diverse learning areas. However, a number of 'stand-alone' thinking skills programmes (for example, Feehrer, & Adams, 1986; De Bono, 1986) are implemented as separated from the traditional content or subject areas (Fogarty & McTighe, 1993:162). The tendency is to teach thinking skills independently of context in a variety of curriculum areas, thus ignoring the importance of content knowledge (Newell & Simon, 1972; cited by Johnson, 1997:164-165). The following range of programmes, models and conceptions of thinking with clear cognitive outcomes were considered in creating a framework for the IWDP:

- *De Bono's (1986) CoRT thinking programme* which includes six thinking strategies/modes. Each strategy/mode has a symbolic name, a 'thinking hat', associated with six basic colours. These thinking strategies/modes cater for learners' needs, like affection, values information, managing thinking skills and creativity.
- *Marzano, Brandt, Hughes, Jones, Presseisen, Rankin and Suthor's (1988) model of core thinking skills*. According to Marzano and his associates the primary dimensions or key aspects of intellectual skills are thinking skills, critical and creative thinking, thinking processes and metacognition. Thinking skills involve the following: focusing, information gathering, evaluating, remembering, organising, generating and integrating. Metacognitive (reflective) skills include self-checking, self-monitoring, advance planning, questioning, summarising, predicting, generating alternatives, and evaluating (Marzano, *et al*. 1988; cited by Johnson, 1997:164).
- *Beyer's (1988, 1991) conceptions of teaching thinking*. According to Beyer (1991:13, 15) each thinking skill consists of attributes such as:
  - a procedure (a series of the steps and sub-steps);
  - a rule or principle (which inform and guide the execution and application of the procedures); and
  - criteria of other knowledge (applied in executing the procedure or following the rules).

  Defining thinking skills and their attributes (Beyer, 1991:5, 15) and communicating this information to the learner, enhance task execution and thinking in general.
- *Conceptions of design skills developed by Carver, Lehrer, Connell, and Erickson (1992).* Carver, *et al.* (1992) mention the following design skills, which must be nurtured in the project-based classroom: project management skills, organisation and representation skills, presentation skills, research skills and reflective skills.
- *Eggen and Kauchak's (1996) conceptions of higher-order thinking.* Higher-order thinking involves knowledge, basic thinking processes, metacognition, attitudes and dispositions. Higher-order thinking consists of reaching a conclusion based on evidence.
- *Ankiewicz, De Swardt and Stark's (2000) model of the technological process and its sub-processes.* The technological process integrates the following clearly identifiable sub-processes: thinking sub-processes (creative and critical), decision making, problem solving and design. "Critical and creative thinking is required for decision making; decision making is necessary in order to solve a problem and problem solving is a prerequisite for design" (Ankiewicz, *et al*. 2000:122). Sub-processes with their associated steps interact with each other as sub-processes of the technological process.

IDENTIFYING PROCESSES OF COMPLEX THINKING RELEVANT TO A PROJECT-BASED CLASSROOM

There is a need for an explicit identification and a clear conception of thinking processes in a technology-based learning environment (Johnson, 1997:172). The clear conception of the processes of complex thinking relevant for the project-based classroom and identifying corresponding thinking skills and their attributes was based on the above conceptions, models and programes of thinking. Particularly the model of the technological process and its sub-processes proposed by Ankiewicz at al., (2000) illustrate the importance and the interdependency between the thinking processes of complex thinking, and their justification in the use in the project-based classroom. For the purpose of this study reflective thinking is incorporated into a separate process although reflective thinking some authors (for example, Greeno, 1989) usually consider as a part of critical thinking. Within an expanded understanding of complex thinking based on the above discussion the following processes of complex thinking and corresponding skills were considered relevant to the nature of web page design:

- *Critical thinking* refers to thinking at a high level of complexity where thinking processes such as generalising, organising, connecting, analysing and evaluating are involved.
- *Reflective thinking* Most authors agree that reflective skills involve the monitoring of the learning process, the connection of new and familiar information in the memory, the 'stop and reflect' approach, selection of important elements in instructional materials, selection of resources, selection of a problem representation, and the selection of an appropriate strategy for problem solving.
- *Creative thinking* The major creative thinking skills of imagining, synthesising, elaborating and insight are considered relevant, together with the general steps of creative thinking: preparation, incubation, illumination and verification.
- *Problem solving* refers to troubleshooting/debugging project development, research and development, scientific process, thinking skills.
- *Decision making* is a cyclic process of determining the objectives, establishing the information domain, considering options and then evaluating results.
- *Designing* basically consists of project management skills, research skills, presentation skills, organisation and representation skills.

A variety of thinking skills were identified within thinking processes composing a rich structure of cognitive components that must be communicated and controlled by learners in the ISD context.

The investigation of the specific nature of complex thinking has been further enriched through an analysis of a variety of instructional strategies applicable to facilitating complex thinking in a project-based classroom. This has led to the derivation of criteria for the instructional web design programme (IWDP). “Criteria are standards or conditions that must be met for something to be judged on example of what it purports to be” (Beyer, 1991:13). Criteria were used to develop a set of the teacher activities and learners’ tasks and activities which were incorporated within the IWDP. Appropriate strategies and criteria for the IWDP will be discussed in the next section.

IDENTIFYING APPROPRIATE STRATEGIES AND CRITERIA FOR FACILITATING COMPLEX THINKING IN A PROJECT-BASED CLASSROOM

The diversity of ideas on thinking indicates that a ‘unified field theory’ of thinking and cognition is not agreed upon (Fogarty & McTighe, 1993:167). Attempts to create a unified perspective on thinking have been almost non-existent. This also applies to thinking strategies as researchers’ perceptions originated in different paradigms. This section highlights a number of strategies and several criteria used for the creation of the IWDP.

Critical Thinking

Critical thinking is the means for making reasoned arguments based on particular standards, and it is essentially analytic, evaluative, selective and rule based (Bailin, 1987:24). Critical thinking can be taught (cultivated) through inventive instruction (Bailin, 1987:27) and through open-ended problems where learners use their own imagination and generation of ideas, and provide an effective way of promoting critical and creative thinking (Wakefield, 1996:459; cited by De Swardt, 1998:42). Johnsey (1995:199) states, "… if the 'end' is the solution to a practical, open-ended problem then, in the broad sense, it can be called the problem solving process. If the 'end' is the fulfilment of a need or a designed product then the design process has been used".

Learners should be taught abstraction skills, which remove some of the detail in order to focus on different components of the information system (Harris, 1999:61). In addition, if reflection and evaluation of ideas are encouraged, rewarded, and expected as part of the normal interactive activity of the group, learners will engage in critical thinking (Greeno, 1989:139). Through reflective thinking, monitoring and evaluating one's own performance and collaborative activities "…in which reflection and evaluation of ideas are encouraged, rewarded, and expected as part of the normal interactive activity of the group" learners engage in critical thinking (Greeno, 1989:139).

Stevens, Slavin and Farnish (1991:10) support the use of dialogue between learners that integrate and reinforce collaborative work by using group goals that are based on individual accountability (Slavin, 1983a, 1990a). Critical is a social phenomenon (Greeno, 1989:139) that can be developed through collaborative learning, but the learners need to provide explanations to one another and they must be motivated (Stevens, *et al*. 1991:10).

Based on the above discussion the following criterion on critical thinking emerged:

CRITERION 1:	Providing open-ended problems, teaching learners abstraction skills, encouraging reflective thinking, monitoring and evaluating one's own performance within collaborative activities and a range of creative strategies promote critical thinking skills in the project-based classroom.

Eggen and Kauchak's (1996) conceptions of critical thinking contain the following route: evidence, inductive and deductive conclusions, and critical thinking. The conceptions of these authors lead to the following criterion:

CRITERION 2:	Critical thinking should be based on evidence that leads to inductive and deductive conclusions.

Jonassen (1996:29) points out that critical thinking involves evaluating, analysis and connecting. In general, critical thinking refers to thinking at a high level of complexity where thinking processes such as generalising, organising, connecting, analysing and evaluating are involved (Ankiewicz, *et al*. 2000:122; Jonassen, 1996:99-100; Fogarty & McTighe, 1993:163; Chubinski, 1996:23). Based on ideas of these authors the following criterion emerged:

CRITERION 3:	Critical thinking skills (generalising, organising, connecting, analysing and evaluating) are applicable to technological design.

Chubinski (1996:23) proposed some strategies for facilitating critical thinking, which are adapted and briefly presented below:

- Identifying the problem: Class discussions are essential for the initial problem definition and for determining relationships between problems.
- Deciphering the purpose: Critical reading is encouraged because it includes the ability to recognise clues and make connections between clues.
- Uncovering assumptions: In small groups learners share ideas and uncover their individual assumptions and biases. A learner is asked to summarise the class discussion up to a particular point including the view the class has taken.
- Recognising and using different paradigms: Another learner in a group is asked to describe a contrasting view.
- Demonstrating different methods of reasoning: Decision analysis is an individual activity that requires a student to record how she or he came to a recent decision using a decision tree or flow chart.
- Examining data: Learners develop a critical reading ability by underlining words, indicating for example facts, frame of reference in different colours.
- Identifying the relationships between data: Case studies are a classic strategy to analyse data.
- Creating alternative solutions: Playing the game 'what if?' helps learners to use their creativity to predict outcomes and create alternative solutions.
- Evaluating one's thinking: Learners evaluate test answers looking for patterns in their decisions using self-questioning.

Based on the strategies proposed by Chubinski (1996) the following criterion emerged:

CRITERION 4:	Chubinski (1996) strategies for facilitating critical thinking ere necessary in the project-based classroom.

Reflective Thinking

Metacognition (reflection) refers to an awareness of, and control over one's own cognitive processing (Flavell, 1976:231-235; Nickerson, 1988:19; Eggen & Kauchak, 1996:53-54) while performing specific tasks (Johnson, 1997:161-180). Research indicates that " … there appears to be a growing consensus that it is beneficial to teach learners explicitly and directly both the concept and the use of metacognitive processes" (Jackson, 1986:32-36; Collins, Brown & Newman, 1989; cited by Johnson, 1997:174). In solving technological problems learners do not know how, when, and why to use strategies for reflection (Jarvis, 1992; cited by Johnson, 1997:174). "The teacher should explain not only the metacognitive strategy, but also how, when, and why the strategy should be employed" (Johnson, 1997:174).

Learners must have both the time and the freedom to think about what is being said, and compare it with his or her experiences (Whitney, 1987:12). Winn (1990:59) states that learners can be trained to acquire the ability to monitor their own performance and to select learning strategies for themselves. The researcher of this study is of the opinion that learners should also have a choice of personal space suitable for self-reflection. Based on these conceptions the following criterion emerged:

CRITERION 5:	Learners must have both the time and the freedom to reflect on their thinking, while explicitly and directly being taught both the concept and the use of metacognitive strategies (how, when and why to use the strategy for reflection).

To create better links between the stages of web page design and thinking, learners should be encouraged to monitor their own thinking processes and the processes they are developing as suggested by Jones (1997:95). Thus, learners should be taught how to learn, remember, solve problems and how to assess their own thinking processes (Perkins, 1986:4; Sternberg, 1985:194). Brown, Campione and Day (1981; cited by Stevens, Slavin & Farnish, 1991:8) state that teaching students self-regulation skills enhances their ability to monitor their own cognitive activities.
The discussion regarding reflective thinking lead to the following criterion:

CRITERION 6:	The ability to plan, monitor and evaluate one’s own understanding, to improve self-regulation and express feelings is essential in the ISD context.

These criteria are vital for an ISD learning environment due to its complexity and the variety of tasks expected from learners.

Creative Thinking

Learners engage in varying degrees of creative and critical thinking during technological design (Johnson, 1997:164). Research shows that there is no strong evidence of successful enhancement of creative thinking through the use of creativity programmes (Hunter-Grundin, 1985; cited by Hennessy & McCormick, 1994:94).

According to Ankiewicz, *et al*. (2000:122) the creative process consists of the following steps: inspiration, clarification, distillation, persistence, evaluation and incubation. There are four general steps in creative thinking generally accepted in the literature: preparation, incubation, illumination, and verification. Norman, Riley, Urry and Whittaker (1990:19) add the step of ‘first insight’ to this list of creative steps:

- First insight (recognition of a problem and an attempt to solve it).
- Preparation (recognising the existence of a problem and acquiring the required knowledge in an attempt to understand and solve problems).
- Incubation (period of relaxation during which subconscious thought processes are active).
- Illumination (seeing a solution; ‘the act of insight‘).
- Verification (testing the idea into a workable solution) (Lawson, 1990:19; cited by Hill, 1998:205).

The investigation of various findings has led to the following criterion for creative thinking:

CRITERION 7:	Creative thinking skills (first insight. inspiration, clarification, distillation, persistence, evaluation and incubation) should be nurtured in technology classrooms.

Mayer (1992:362) suggests that creative thinking involves the ability to generate alternative solutions, the ability to evaluate solutions, originality, importance (the usefulness of a solution), flexibility (the number of different categories or approaches to the problem), and elaboration (the number of embellishments to an idea). The major creative thinking skills of imagining, synthesising, elaborating and insight are particularly relevant for web design because they are widely referenced in the literature Ankiewicz, *et al.* 2000:122; Jonassen, 1996: 99-100; Fogarty & McTighe, 1993:163; Mayer, 1992:362). Teachers should encourage insight skills such as "… the ability to focus on relevant data, to separate between relevant and irrelevant data, to seek new and productive ways of combining information, and to see a correlation between our present level of information and the solution demands of new and emerging problems" (Hunter, 1993:106).

The investigation of various theoretical and empirical findings has led to the following criterion for creative thinking:

CRITERION 8:	General steps in the creative process and the skills of imagining, synthesising, elaborating and insight are relevant to the web page design process through which learners have an opportunity to investigate and create a web site.

According to Greeno (1989:140) recognition and restructuring of ideas, social relationships, and methods of interacting with the physical environment plays a role in promoting creative thinking. Schlichter (1991:8) points out that brainstorming and drawing up a list of ideas, and challenging learners to examine alternatives and then to defend decisions are some strategies in stimulating creative thinking.

Classroom teaching should include activities that are performed through collaborative work, aimed at socially constructed understanding and thinking (Greeno, 1989:139). Greeno (1989:140) points out that through design in a collaborative group, "…learners naturally apply their intuitions in constructing explanations and interpretations, and they and the other members of the group reflect on these, making learners more articulate. Social support for creative activities undoubtedly plays a crucial role".

Based on these findings the following criterion emerged:

CRITERION 9:	Interactions in the social environment and stimulating recognition and restructuring of ideas, and interacting with the physical environment promote creative skills.

Problem Solving

Problem solving is enhanced through learners attempting 'real world' technological problems, because design and technology rely heavily on experience (Shield, 1996:1-14; Newman, 1990:52). A more coherent picture of problem solving strategies which could be useful in the project-based classroom, is offered based on different views of problem solving.

The starting phase in ISD is problem identification and specification, which demands fact finding as well as a diagnosis accomplished through industry research, on-line research, personal contacts (interviews, observation, questionnaire) and documentation review (Harris, 1999:40). Thus, learners should be taught research techniques during the initial stage of problem solving.

The discussion of an empirical justification for the transfer of problem solving capabilities in different contexts (Hennessy & McCormick, 1994:98) indicates that problem solving processes are not a set of predefined sequential steps independent of a specific practical context. Problem solving is context specific, with the emphasis on knowledge and reflection (Jones, 1997:92). Although thinking skills taught in the context of a particular subject are more likely to transfer to other similar domains (Beyer, 1984:556; Perkins & Salomon, 1988; cited by Schlichter 1991:7), it seems equally important to refer to the learner's own experiences and choices of real-life problems. Learners should be encouraged to make sense problems based on their experiences (Vockell & Deusen, 1989, Dick, 1991; Mayer, 1992). This contributes to familiarity and the enhancement of thinking.

Since each individual's knowledge structure is unique, based upon his/her own set of experiences and abilities, the ways that an individual prefers to access, interact with, and interrelate information is also unique (Jonassen, 1988:14). Teaching problem solving depends on human dimensions including previous technological knowledge, and personality characteristics (Custer, 1995:238). Technological skills together with subject knowledge are prerequisites for deeper solution-generation and evaluation techniques during problem solving. Thus, learners rely on their own problem solving abilities, technological skills and knowledge.

Based on the previous theoretical findings the following criterion was derived:

CRITERION 10:	Problem solving should be based on learners' real experiences, abilities, research skills and knowledge in a context dependent environment.

Wheatley (1991:14) discusses the idea of problem-centred learning, which involves problematic tasks that focus attention on the central ideas of a discipline. Setting up problematic tasks with the teacher's guidance, a learner is able to construct effective ways of thinking in a specific subject area. The teacher establishes settings for meanings and sets activities for learners, which require reconstruction of ideas at higher levels.

Mayer (1992:70) suggests that "… there is growing evidence that under appropriate conditions concrete representations including illustrations and animations, can improve problem solving performance". In addition, Hennessy and McCormick (1994:95) conclude that formal procedures for problem solving applied in unfamiliar learning conditions, which are divorced from reality, are unproductive.

Based on the conceptions of these authors the following criterion emerged:

CRITERION 11:	Problem solving requires setting up problematic tasks, open-ended, real-world problems, concrete representation and an analysis of the structural features of a problem situation.

Thinking skills demand particular techniques in order to process relevant information in a knowledge base (DeLuca, 1992:26). Presseisen (1985:45) discusses the importance of various techniques for problem solving which are relevant for this study:

- Qualifications (finding unique characteristics: definitions, problem/task recognition)
- Causation (establishing cause and effect; predictions, inferences)
- Relationships (detecting parts and wholes; patterns; analysis and synthesis; sequence and order; logical deduction)
- Classification (determining similarities and differences; grouping and sorting; comparisons)
- Transformation (creating meanings; analogies; logical induction).

Research shows that classroom learning is artificially constructed and problems are pre-formulated (Hennessy & McCormick, 1994:99). This leads to adherence to learners' own "reliable and far more flexible intuitive problem solving methods". Therefore, problem solving skills and procedures could be linked to the informal problem solving strategies suggested by Johnson (1997:161-180). In addition Johnson (1997:175) state that novice problem solvers without extensive technological knowledge need "… modelling, coaching and scaffolding". A range of ideas has led to the derivation of the following criterion:

CRITERION 12:	Encouraging informal problem solving strategies with modeling, scaffolding and coaching contributes to efficient problem solving skills of learners in the ISD context.

Problem solving in an ISD context consists of the process of a series of incremental solutions, which lead to the final product (Harris, 1999:23). The proposed criteria on problem solving cater for a wide range of requirements for effective problem solving in an ISD context.

In summary, literature findings highlight research skills (Harris, 1999) the importance of real experience (Shield, 1996; Jonassen, 1988) learners' own problem solving abilities (Jonassen, 1988), concrete representation of problems (Meyer, 1992) setting problematic tasks (Wheatley, 19991) and informal problem solving procedures (Hannessey & McCormick, 1994) as adequate for the facilitation of problem solving in the ISD context.

Decision Making

To solve information system problems, which demand fact-finding, diagnosing and the learning techniques of decision making, some basic information processing requirements must be satisfied, namely information relevancy, accuracy, timelines, usability, affordability, adaptability, and accessibility (Harris, 1999:36). "Decision per se, takes place when a goal is specified, when information is gathered and judged, when values are used to choose the best solution, and when detailed plans are made and evaluated" (Wales & Nardi, 1984:681).

Decision making can be improved by means of effective training programmes (Shanteau, Grier, Johnson & Berner, 1991; cited by Halpern, 1996:205; Halpern, 1996:301) and decision worksheets. Knight and Danserau (1992:261) used decision worksheets to train college learners which positively influenced their decision making process.

According to Feehrer and Adams (1986:iii) strategies that can be used in order to facilitate learners' decision making, include assessing the likelihood of outcomes, deciding on the relevance of information, deciding on the consistency of information, deciding on the credibility of information, expressing preferences and weighting dimensions. The above theoretical views and perspectives on decision making (Knight & Danserau,1992; Ruggiero, 1995; Halpern, 1996; Feehrer & Adams, 1986) provide a basis for devising the following criterion:

CRITERION 13:	Assessing the likelihood of outcomes, deciding on the relevance of information, deciding on the consistency of information, deciding on the credibility of information, expressing preferences and weighting dimensions are essential in promoting decision making in the project-based classroom.

Learners are performing different decision making steps until the best alternative is chosen and an action performed. They re-evaluate, re-generate a decision based on outcomes. Halpern (1996:282-283) proposed steps for making a successful rational decision. The following steps are considered relevant in a project-based classroom:

- The realisation that a decision is needed.
- Setting clear objectives (objectives can help to identify possible courses of action, providing criteria for evaluating alternative options and assessing the quality of the final decision).
- Seeking, organising and analysing relevant information.
- Establishing options (each alternative has several pro's and con's associated with it).
- Thinking creatively and critically about options, analysing each option according to its strengths, weaknesses, opportunities, and threats (Ruggiero, 1995:68; cited by Halpern, 1996).
- Reframing the decision so as to consider different types of alternatives.
- Recognising the need to seek disconfirming evidence and deliberately seeking disconfirming evidence.
- Preparing a decision making worksheet to improve the decision making process.
- Evaluating desirable and undesirable consequences against criteria derived from the objectives.
- A choice is made which leads to action and, hopefully, to meeting the objectives. Decision making always involves making a choice among a set of possible alternatives.

Steps for making a successful rational decision proposed by Halpern (1996:282-283 serve as a basis for the derivation of the following criterion:

CRITERION 14:	Steps for decision making (Halpern 1996) which promote learners decision making processes and highlight reflection and insight are relevant in the project-based classroom.

Design Process

Johnsey (1995:214-215) suggests that students should be taught in a variety of strategies in order to deal with the design process in different contexts. Technological projects confront learners with different problems that require different approaches (McCormick, Murphy & Hennessy, 1994:5). These authors state that problem solving and design skills learnt in any other curriculum subject are not transferable to design and problem solving in a technological learning context. Knowledge must be reconstructed, integrated and contextualised for design purposes in technological projects (Layton, 1991:43).

Educational research emphasises the value of students actively designing knowledge (Jonassen, 1996; Carver, *et al.* 1992:385). Design encompasses the development of technological solutions for given needs, while problem solving entails the search for solutions for given technological problems (De Vries, 1999:20).

The role of adequate subject knowledge should not be ignored (Smithers & Robinson, 1992; cited by McCormick, *et al.* 1994:5). Knowledge of structures, electronics, materials and the understanding of a design approach is central to technological problem solving (Shield, 1996). Web page design relying on the technological process requires a certain level of programming knowledge. This might contribute to familiarity of the context based on the expert knowledge necessary for successful design (Johnsey, 1995:215). In addition, there is a need for specific design procedures such as redefining the design problem repeatedly. In other words, it is difficult to know what problems are relevant and what information will be useful until a solution is attempted (Lawson, 1980; cited by Johnsey, 1995:206).

The process of modeling should not be ignored during the development of design and thinking skills (Welch, 1998:244). Thus, learners should think through and communicate design procedures to themselves and to other members of a design team (McCormick, *et al.* 1994:20). Researchers agree that design skills are neither clearly structured nor rule based. Therefore, learners need a cognitive support such as 'cognitive apprenticeship', which involves initial instructions, modeling, coaching and scaffolding (i.e. prompts or support) and fading (Brown & Campione, 1986; cited by Stevens, *et al.* 1991:9). Also, Hunter (1993:108) reveals that learners need encouragement and role modeling.

Heywood (1986; cited by Shield, 1996:1) discovered that learners had difficulty in identifying a problem and writing critical reviews of some of the technological activities. Learners should be encouraged to sense the technological problem and to investigate the context of their design tasks (National Curriculum Non-statutory Guidance, 1990; cited by Johnsey, 1995:208). Learners should be involved in identifying needs and opportunities through the investigation of the context, while teachers are more involved in setting the task (National Curriculum Non-statutory guidance, 1990; cited by Johnsey, 1995:204). Also, learners are to be encouraged to develop criteria against which products can be evaluated, before developing their design proposal.

McCormick (1997:150-151) points out that a step of the design process such as 'generating ideas' or 'evaluation' must be taught to learners as a range of techniques. He suggests the use of brainstorming techniques, and argues that teachers should not structure projects with prescribed steps that take away strategic planning, decision making and thinking. However, some guidelines on design structures (for example, task identification, investigation, generation, and development and evaluation) are necessary, but not to be taken as discrete steps in the design process (Johnsey, 1995:214).
Based on different ideas regarding technological design the following criterion emerged:

CRITERION 15:	Technological design should occur in familiar situations, explicitly set as a goal-directed environment through which modelling, setting guidelines and encouraging the development of criteria, and an understanding of the purpose of the design are emphasised.

According to Wertheimer (1959:212) learners should understand the overall structure of the problem. This idea is in agreement with Perkins's (1994:5) conception of 'knowledge as design': establishing the purpose and the structure; modeling cases; evaluating arguments, pro's and con's; explanatory arguments; and closure. Learners involved in the technological process must be able to expand the design, to see the structure of a project, and to visualise the project as a whole and as a dynamic process. Perkin's (1994) ideas influenced the derivation of the following criterion:

CRITERION 16:	The design process should have the following general steps: establishing the purpose and the structure; modeling cases; evaluating arguments, pro's and con's; explanatory arguments; and closure.

The emphasis should be on the specification of what the design is to achieve against the evaluation of the product (Johnsey, 1995:209). In other words, the process of evaluation depends on understanding the link between defined problems and the solutions they seek (McCormick, *et al.* 1994:7). Self-evaluation of a design requires learners to understand the purpose of the design processes (Perkins, 1994); the understanding of what to evaluate; and how to evaluate it (McCormick, *et al*. 1994:7). These aspects are equally important while generating design ideas, identifying needs, or creating a specification.

In the context of ISD, where design skills are essential, a clear model of design skills and their attributes are required. Carver, *et al.* (1992:385-404) conceptions of design skills (project management skills, research skills, presentation skills, organisation and representation skills) and Beyer's (1991:5-19) ideas on thinking skills and their attributes (a procedure, the rule or principle, criteria) could help us delineate skills and steps for learners engaged in creating a web site, and shape instruction in a project-based classroom.
Based on different ideas proposed by Beyer (1991) and Carver, *et al.* (1992) regarding design skills the following criteria emerged:

CRITERION 17:	Self-evaluation of a design requires learners to understand the purpose of the design process and the following skills: project management skills, research skills, presentation skills, organisation and representation skills.

CRITERION 18:	Defining thinking skills and their attributes (a procedure, the rule or principle, criteria) whilst communicating this to the learner enhances the execution of tasks and thinking in general

The criteria for the development of design skills are primarily based on McCormick's (1997), Perkin's (1994), Carver et al (1992) and Beyer's conceptions of design skills and thinking in general. The learners in a project-based classroom should be encouraged to use imagination and inventiveness to make connections between ideas.

Educators need to define and understand the thinking skills in any context by deciding "…how to execute skills, when and where it is appropriate to employ the skills, how to imitate its use, and what to do when the skill does not work" (Beyer, 1988; cited by Beyer, 1991:13). The learner and the teacher must take control of the thinking processes during design activities.

Halpern (1996:282-283) notes: "… decision making, problem solving, and creative thinking have a great deal of overlap in the way they are conceptualised". The integrated nature of critical and creative thinking, and problem solving (Walters, 1990:450; Trow & Hadden, 1976:26; Mebl, 1997:34) implies that criteria are linked. Criteria support each other, their relation is established in their constructivist theoretical foundation and some of criteria may be merged. For example, problem solving and critical thinking depend on research skills, abilities and experience of learners as well as the real world nature of the problem.

The following paragraphs deal with some issues and instructional aspects relevant to the facilitation of complex thinking in a project-based classroom.

DISCUSSIONS

The processes of complex thinking required for them need to be explicitly taught in a project-based classroom while preparing learners for ISD. In addition to different ideas for facilitating thinking processes, Beyer' (1991) ideas were considered essential for promoting learners' self-awareness, control and monitoring of their thinking processes.

In line with research findings it comes as no surprise that the technological environment influences technological problem solving (Ankiewicz, De Swardt & Stark, 2000). Providing the technological environment in which a collaborative effort is nurtured through the creative involvement of the teacher (Eggen & Kauchak, 1996:323) and reflection by learners could influence thinking outcomes in a project-based classroom. DeLuca, (1992:29) remarks that a "teacher should establish a sequence of instructions that will lead learners to independent thinking", thus creating a conceptual overview of a system and helping learners to remain on track.

Organising an instructional environment which stimulates learners' imagination and generation of ideas provide a sensible way for promoting thinking (Hunter, 1993). In such learning environments learners must have opportunity to find a problem, select and evaluate solutions (Greeno, 1989). This can ensure that critical thinking skills are built through a series of strategies proposed by Chubinski (1996).

In facilitating critical thinking the personal characteristics of learners play an important role (Custer, 1995). In addition, researchers emphasise the relevance of the technological problem to learners' experience, knowledge base, interest and desires (Dick, 1991; cited by Blignaut, 1993:21; Hennessy & McCormick, 1994:103-105; Hill & Hopkins, 1997; cited by Hill, 1998:216).

Research findings support the importance of sufficient time allocation for learning processes (Hill, 1998:212; Whitney, 1987:23) particularly in developing creativity (De Swardt, 1998). Learners must have the time and the freedom to think of what is being said, and be able to compare it with their experiences (Whitney, 1987). Learners should rely on their own perseverance, creativity, self-confidence, and higher order thinking during the project design (Paul, 1993:282; cited by De Swardt, 1998:55) as it requires considerable time.

Greeno (1989:140) emphasised the role of group support for creative thinking. Interactivity contributes toward activity-based practice in a collaborative learning environment and is equally important as a constructivist strategy in teaching and learning. While sharing the problem situation in collaborative environments, learners develop problem solving and thinking techniques (Wheatley, 1991:19; cited by De Swardt, 1998:51). Collaborative learning includes shared knowledge and understanding (Greeno, 1989:139) in an emotionally supportive context (Reid & Stone, 1991:9).

The literature review indicates that learners need a variety of instructional strategies to support their thinking skills. Learners should be exposed to methodologies such as goal-setting, inquiry techniques, assimilation of concepts or ideas, classification which include clarification and discussion, activity–based practice and demonstration of accomplishment (Maley, 1978:5; cited by Edminson, 1995:27-28) in order to develop their cognitive skills.

IMPLICATION FOR INSTRUCTION

A variety of instructional strategies combined with cognitive apprenticeship, visual means, an explicit modelling of thinking skills and their attributes could promote a positive thinking atmosphere. Learners need to develop an understanding of thinking processes, under the creative facilitation of the teacher, providing sufficient time and activity-based practice.

Integrating the task-based and collaborative learning environment with the real-world nature of the problem based on learners' own experience provide an essential foundation for establishing a thinking climate in a project-based classroom. Designing instruction around this integration and incorporating expert teaching, explicit guidance and collaborative work can help learners to develop thinking skills.

The creation of an effective task-based learning environment in the ISD context is possible in conjunction with explicit teaching of appropriate thinking skills and their attributes. This will enlarge and strengthen the learners' insight into thinking skills and set a climate for enhancing complex thinking in the ISD context. Research findings support the virtues of constructivist instructional strategies, as well as sensible and multiple interactions in a project-based classroom for improving learners' thinking skills.

Thinking is conceived as a reorganisation of links in a learner's cognitive structure. The more links that can be formed between thinking processes, the better the utilisation of thinking will be during ISD. If a certain stage of critical thinking is reached it triggers other thinking processes provided that some internal or external pressure exists which gives learners endurance during a creative thinking effort.

The creativity process seems to increase in an exponential way, meaning that the generation of one idea leads to other ideas. The teacher should facilitate the processes of generation, refinement and realisation of ideas. However, explicit procedures need to be developed to lead learners from an idea through the process of realisation. A creative atmosphere in a project-based classroom should be nurtured over a long period of time until learners' enjoyment, habit and independence are established.

In conclusion, different ideas on complex thinking can be used for further investigation of a variety of aspects relevant for improving the thinking skills of learners in the ISD context.

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A setting of criteria on problem solving*Development of problem solving:* Research shows that problem solving is ideal when used in conjunction with cooperative learning. Pea (1987:639) recognises the importance of solving problems collaboratively. It is generally accepted that problem solving is better accomplished within a collaborative learning environment, where learners are involved in authentic activities that reflect a collaborative atmosphere. In the process of sharing a problem situation in a collaborative learning environment, learners develop problem solving abilities and thinking abilities in general (Wheatley, 1991:19; cited by De Swardt, 1998:51). Verbal communication among learners aids the restructuring of information (Slavin, 1990b; cited by Johnson, 1997:172), focusing on the problem-solving task (Glass, 1991; cited by Johnson, 1997:172). Vygotski's (1978) idea about the need for extensive verbal interactions between adults and learners can be easily attended in a collaborative learning environment

Enhanced learning: According to Laurillard (1994:171-173) learners share opinions with one another, thus providing a description, which enhances his or her point of view. Similarly, Haste (1987; cited by Wheatley, 1991:18) states that "…participating in small problem solving groups can stimulate cognitive disequilibria, such that there is a measurable change over time in the structure of thinking". Peer coaching provides an opportunity for "…analytical observations and thoughtful dialogue" in a classroom atmosphere (Fogarty & McTighe, 1993:167). Enhanced learning could be achieved through assigning additional roles in the collaborative groups. Specialised roles could be assigned to learners as so called 'task specialisation' (Eggen & Kauchak, 1996:296) in reaching the goals of activities.

Thus, these criteria highlight a variety of decision making strategies, which may be improved through effective training programmes, decision worksheets and brainstorming.

To solve information system problems, which demand fact-finding, diagnosing and the decision making, some basic information processing requirements must be satisfied, namely information relevancy, accuracy, timelines, usability, affordability, adaptability, and accessibility (Harris, 1999:36).

When learners design a web site they must decide on a plan of action. The decision-maker bears the responsibilities for the timeline for the completion of the project: specific information that should be involved; how information should be represented; how information should be accessed, developed, interpreted, partitioned, connected and organised.

The decision making process is a cyclic process of determining the objectives, establishing the information domain, considering options and then evaluating results (see Figure 3.10). Learners need explicit guidance in developing a range of decision making skills. (see Figure

- It appears important for learners to produce descriptions of their design and research processes involved in designing, making and planning (Johnsey, 1995:212).