INSTRUCTIONAL METHODOLOGY FOR TECHNOLOGICAL PROBLEM SOLVING IN PROJECT-BASED CLASSROOMS

[1]Maria Jakovljevic & [2]Piet Ankiewicz
[1]School of Computing, University of South Africa.
[2]Department of Science and Technology Education, University of Johannesburg, South Africa.
e-mail: jakovm@unisa.ac.za; pieta@uj.ac.za

Abstract
Real issues of web design and development include many problem solving tasks. There are, however, some inadequacies associated with the implementation of appropriate instructional methodology for organised and structured instruction that support the rational problem-solving paradigm. The purpose of this article is to identify criteria for the design and development of the Instructional Web Design Programme (IWDP) with methodology-specific guidelines in an information systems design (ISD) context. Furthermore, the purpose is to devise a structure and relevant components of the instructional programme, which can support technological problem solving through appropriate strategies and learning modes. A qualitative, action-research approach was the basis for this study. The sample consisted of seventeen learners at an institution of higher education. The researchers used a focus group interview, journals and essays to observe learners' behaviour, to analyse their project designs and to assess their opinions and experiences with regard to the IWDP. An organised and structured instructional environment within the IWDP helped the teacher to promote technological problem solving. The teacher and learners acknowledged the components of the programme (for example, assessment criteria, range statements, performance indicators, pre-defined learner tasks and activities) in the project-based classroom.

Keywords: Instructional Methodology, Technological Problem Solving, Technological Process, Project-based Classrooms, Information System Design, Instructional Programme

1 INTRODUCTION

According to Balfanz (1991) and Johnson (1997), teaching in an IT technology classroom is not suitable for the development of cognitive skills. In the relevant literature (for example, Bednar, Cunningham, Duffy and Perry, 1992; Winn, 1990) there is a remarkable absence of discussions about explicit facilitation of a wide range of thinking skills that learners should develop in an information systems design (ISD) context (Jakovljevic 2002, p.244; Jonassen 1996). Real issues of web design and development include multiple tasks (Pfleeger 2001; Pressman 2005). Learners experience the entire process of requirements driven design (RDD) during the systems analysis stage, through clear definition of basic requirements of the proposed system through fact-finding techniques: interview, questionnaire and diagramming. Requirement specification forms input into the design phase, which will define how systems will operate (Castro, Kolp and Mylopoulos 2002; Griffiths 1998; Avison and Fitzgerald 1996; Flynn 1992).

The scope of requirement specifications includes further learner tasks such as functional requirements, user interface layout and output requirements. However, these and other tasks are not sufficiently supported by the present instructional strategies, which neglect the rational problem-solving paradigm (Van Niekerk, Ankiewicz and De Swardt, 2010, p.195; Ankiewicz, 2003, p.18; Ankiewicz, De Swardt, and Stark 2000). The outcomes-based curriculum in South Africa is aimed at developing creative problem-solving skills in every learning area (DoE 1997, p.14-21; South Africa 1997, p.13). Learners lack the skills to clearly define the problem; techniques to handle the available data and to understand the methods of problem solving (Cotton 1995, p.140).

Technological problem solving is the backbone of teaching and learning in the IT technology classroom (Elmer, 1996; Ankiewicz, and De Swardt, 2002; Ankiewicz, 2003; Jakovljevic, Ankiewicz, De Swardt and Gross 2004) but the instructional environment efficient for promoting problem solving needs further investigations (Cotton, 1995; Beyer 1991; Eggen and Kauchak 1996). Based on the above discussion, the purpose of this article is to:

1. Identify criteria for the development of the instructional web design programme (IWDP).
2. Set a structure and related components for the instructional programme that could positively influence the problem-solving environment, and
3. Identify and discuss key instructional strategies and learning modes, which can support technological problem solving.

To do this, the following research questions were set:

1. *What criteria for the IWDP development can be derived from the learning theories, instructional models and strategies in order to create an appropriate instructional environment for addressing technological problem solving?*
2. *What should the structure and relevant components of the IWDP entail?*
3. *What instructional strategies and modes of learning have supported technological problem solving?*

2 THE THEORETICAL FRAMEWORK FOR THE DEVELOPMENT OF THE IWDP

2.1 Basis underlying the development of IWDP

A theoretical framework based on learning theories, instructional models and strategies, programs, models and conceptions of higher-order thinking, and mind tools were essential pillars in the development of the IWDP. These pillars provided a wide range of interdisciplinary issues together with the conceptions of the Illustrative Learning Programme and the roles and competencies of the teacher in the IT technology classroom (Jakovljevic, Ankiewicz, De Swardt and Gross 2002).

2.2 The role of learning theories, instructional models and strategies

Several principles derived from the behavioural instructional approach are necessary for certain types of low-level performance in the project-based classroom: contiguity, repetition, feedback and reinforcement (Clark and Lampert 1986; Johnson, 1997; Smallwood 1995; Jakovljevic 2002). Constructivists emphasise the need for active learner involvement and the development of reflective awareness during learning processes (McCormick 1997; Winn 1990), realising the idea of 'knowledge as design' (Perkins 1994). The situated view of learning emphasises the learning experience that is situated in physical real-world and social contexts (Bednar, et al. 1992; Rogoff et al. 1984). Participating in small problem-solving groups can stimulate cognitive disequilibria (Wheatley 1991). Peer coaching provides an opportunity for analytical observations and thoughtful dialogue (Fogarty and McTighe 1993). When developing an instructional programme it is necessary to identify and describe the essential criteria that reflect the teaching and learning in a project-based classroom. This will be discussed in the following section.

2.2.1 Essential criteria for the IWDP derived from learning theories, instructional models and strategies

The researchers derived the criteria that served as a basis for the development of the IWDP (Jakovljevic 2002). For purposes of this article, the most prominent criteria derived from learning theories, instructional models and strategies are presented in Table 1.

Table 1: Criteria drawn from learning theories, instructional models and strategies

Criteria for the IWDP based on learning theories, instructional models and instructional strategies
1. Direct teaching and fostering observational learning during demonstrations are essential for acquiring factual knowledge and basic skills in the project-based classroom.
2. Technological design should be taught through a guided discovery approach, where learners are not presented with the subject matter in its final form.
3. Cognitive and practical apprenticeship with coaching, scaffolding and prompting in a collaborative learning environment is essential in the project-based classroom.
4. In web design, instructional strategies that support reflective practice, activity-based practice, and peer-based learning help learners to develop intellectual skills.

5. When applying a constructivist or behavioural instructional approach, a variety of instructional strategies (for example brainstorming, inquiry/investigation, discussions, case studies, activity based practice and project work) are essential for technological problem solving.

The above-mentioned prominent criteria served as a basis for developing learner tasks, activities and outcomes (see Table 2).

Table 2: Examples of learner tasks, activities and outcomes (Jakovljevic, et al. 2004)

Description of learner tasks (Lt)	**Description of learner activities (La)**	**Description of learning outcomes (Lo)**
LT1. Analyse off-line and on-line marketing techniques related to car purchasing schemes.	La1: Conduct research in a library. La2: Organise an interview with a person responsible for marketing tasks and discuss marketing tools, techniques and procedures involved with car purchasing schemes. La3: Search the popular websites related to business-to-customer relationships.	Lo1: Searching the internet and documents for purchasing policies and schemes. Lo2: An interview transcript (with a person responsible for marketing tasks) and a table of findings. Lo3: A chart of resources and a summary of marketing off-line and on-line tools, techniques and procedures.
LT2. Reflect on the purpose of developing on-line solutions for an effective purchasing scheme yourself. LT3.How can this task contribute to your personal development?	La4: List the advantages and disadvantages of the existing car purchasing schemes. La5: Write down your opinions and perceptions about the proposed website. La6: Reflect on your past experiences through self-direction and other metacognitive skills. La7: Observe the teacher while she performs reflective strategies through modelling.	Lo4: A short essay containing: • Experts' opinions and perceptions about the proposed website • Reflections on the pre-construction process with constructive suggestions.

LT4. Set the envisioning phase of the development (modelling) process.	La 8: Visualise a sequence of design steps. La9: Present a design in the form of a computer-generated map. La10: Brainstorm ideas with regard to the plan and strategies, information style and multimedia design features. La11: Indicate the steps to be taken on a planning list. La12: Do interactivity planning, interface and navigational map design according to the checklists and guidelines. La13: Decide on the segmentation of information. La14: Draw detailed designs (scripting, and multimedia assets).	Lo5: A chart containing: • Project goals • Tasks to reach project goals • A plan to accomplish the tasks • Steps to implement the plan • Criteria to evaluate the plan Lo6: A list which contains: • The plan and strategies • Information style • Interactivity design Lo7: Multimedia design: • A computer-generated map that contains detailed design features.

Learner activities in a project-based classroom (see Table 2) require different modes of learning (the situated view of learning, experiential underpinning supported by cognitive apprenticeship, inquiry learning and peer-based learning) (Bednar, et al. 1992; Rogoff and Lave 1984; Johnson and Johnson 1991Magadla 1996; Duffy and Cunnigham 1997; Johnson 1997). Focus now shifts to programmes, models and conceptions of higher-order thinking.

2.3 Programmes, models and conceptions of higher-order thinking

The development of the IWDP was based on an in-depth investigation of higher-order thinking processes (Jakovljevic, Ankiewicz, De Swardt and Gross 2004; Jonassen 1996). The researchers considered the following range of programmes, models and conceptions of higher-order thinking in creating a framework for the IWDP:

- *De Bono's (1986) CoRT thinking programme,* which includes six thinking strategies.
- *Marzano, Brandt, Hughes, Jones, Presseisen, Rankin and Suthor's (1988) model of core thinking skills* with the primary dimensions of intellectual skills: thinking skills, critical and creative thinking, thinking processes and metacognition.

- *Beyer's (199, p.13, 15) conceptions of teaching thinking skills and their attributes*: Each thinking skill consists of attributes: a procedure, a rule or principle, criteria of other knowledge.

- *Conceptions of design skills developed by Carver, Lehrer, Connell, and Erickson (1992):* (project management skills, organisation and representation skills, presentation skills, research skills and reflective skills).

- *Eggen and Kauchak's (1996) conceptions of higher*-*order thinking* which involves knowledge, basic thinking processes, metacognition, attitudes and dispositions.

- *Ankiewicz, De Swardt and Stark's (2000) model of the technological process* which integrates the following clearly identifiable sub-processes: thinking sub-processes (creative and critical), decision making, problem solving and design (Van Niekerk, et al. 2010). Next section will examine mind tools that support learners' tasks, activities and outcomes.

2.4 Mind tools foster meaningful learning

Mind tools foster constructive learning (Simons 1993; Lehrer1993) and *vision* that is the most powerful human sense, having 'evolved to notice spatial relations such as connectedness, juxtaposition and gaps' (Boden 1990, p.101). The following mind tools are considered necessary:

- Computer programming facilitates the development of abstract thinking, problem solving and logical thinking (Dover 1983).
- Semantic networks are representations of ideas and their interrelationships within the human memory structure (Jonassen, Beissner and Yacci 1993; Jonassen 1996).
- Computer-mediated communication (CMC) acts as a vehicle for delivery and sharing the product of any mind tool (Jonassen, 1996). CMC enhances collaborative learning and thinking through negotiating meaning and sharing of ideas (Hiltz 1986, p.95; Jonassen 1996, p.148, Mabrito 1992, p.27). Next section will explore instructional methodology.

2.5 Innovative instructional methodology within the IWDP

2.5.1 The description and the purpose of the IWDP

The IWDP is designed to accomplish two interrelated purposes. The first purpose is to help learners advance a deep understanding of technological design with specific application to web page design. The second purpose is to promote problem solving skills and values of learners through a variety of instructional strategies and resources. The IWDP focuses on the two strands 'technological process' and 'communication', located in the Further Education and Training band in the IT learning area. The IWDP relates to different instructional strategies and modes of learning including a network of human resources:

- *Instructional strategies/different modes of learning*: individual learning, collaborative learning, inquiry learning, apprenticeship learning, peer tutoring within and across the groups, situated learning, observational and experiential learning.

- *Human resources:* The teacher, peer-tutors, a senior tutor, an assistant, an expert are involved in different interactions in facilitating technological design. Similarly, at Sheffield Hallam University, projects in schools are guided by a network of advisors, subject associations and mentors (Cavan 2007). The aim of the next section is to explore the structure and components of the IWDP.

2.5.2 The structure and components of the IWDP

In addition to structuring the IWDP according to the framework for the national school curriculum in South Africa, the following *components* were identified:

1. *Theme:* Ensure that learners get guidance in terms of a real-world problem.
2. *Critical outcomes (COs):* are generic cross-curriculum outcomes, which ensure that learners gain the skills, knowledge and values, which contribute to a wider community.
3. *Specific outcomes (SOs)*: include technological knowledge, skills, attitudes and values that help learners to understand and demonstrate achievements in technological contexts.
4. *Assessment criteria (*AC) form the standards against which performance will be judged.
5. *Range statements (RS)* include the critical areas of content, processes and context which the learner should engage in to reach an acceptable level of achievement (DoE 1997).
6. *Performance indicators (PI)* provide details about the content and processes that learners should master, as well as details about stages learners need to achieve in learning context.
7. *Case study tasks* help learners to link the problem to the community outside the classroom, build a knowledge base and set the base for resource and capability tasks.
8. *Resource tasks:* are short, practical activities which engage learners' thinking processes and help them to develop knowledge and skills (Givens and Barlex 2001, p.138).
9. *Capability tasks* help learners to demonstrate cognitive, psychomotor and technology-related skills, content (subject matter) knowledge, values and attitudes and to utilise technological problem solving (Jakovljevic, et al.2004).
10. *On- and off-line activities:* are allocated to each task within the technological stages.
11. *Teacher activities (instructional strategies*): are developed to facilitate learner activities.

There is a need for more comprehensive pictures on the stages of the technological process.

2.6 The stages of the technological process

The *technological process* relates to "…identifying needs and opportunities, exploring problems and constraints, gathering information from a variety of sources, modelling and testing production and evaluation" (Jones 1997, p.90). The technological process includes ten stages: Statement of the problem; Design brief; Investigation; Proposal; Initial ideas; Research; Development;

Planning; Realisation/Making; Testing, Evaluation and Improvement. These stages of the technological process are cyclical and repetitive (Ankiewicz et al. 2000; Van Niekerk et al. 2010). Each stage of the technological process consisted of a variety of learner tasks and activities, as well as reasonable time limits allowing learners to achieve an outcome (Ankiewicz et al. 2000; Van Niekerk et al. 2010). Furthermore, for the each stage of the technological process appropriate AC, RS and PI are derived as well as the reasonable time which allows learners to attain an outcome. The next section outlines in more detail the research methodology used, while the research findings are presented and discussed in the fourth section.

3 RESEARCH DESIGN

3.1 Research approach

This research can be described as a qualitative, single case study as the learning experience of learners relates to a specific event in a bounded context (Creswell 1994; Leedy and Ormrod 2005). According to Merriam (1998:41) "case studies have proven particularly useful for studying educational innovations for evaluating programs". To improve the facilitation of technological problem solving it was necessary to change instructional strategies through the application of the following stages of action research: diagnosing, action planning, action taking, evaluating and specifying learning (Baskerville and Wood-Harper 1996).

3.2 Learner profile, intervention and settings

In this study two distinct mixed cultural groups of learners were identified. The two groups respectively consisted of five second-year learners enrolled for the Information Systems Diploma at a Technikon and 12 first-year students enrolled for the International Diploma in Computer Studies at a Higher Education Institution. Most students were from a middle socio-economic environment. Participants from the two groups presented a purposive convenient sample (Patton 1980, p.104). Learners were chosen as their profiles fitted the following criteria: willingness to participate in the research; knowledge of a programming language; team preparedness; and a positive attitude towards the course (Jakovljevic, 2002). The researcher, who also played the role of the teacher, organised an extra-curricular classroom in a well-equipped computer centre at a university and presented the IWDP to teach students web-design skills and to facilitate problem-solving skills (Jakovljevic 2002). The teacher presented the IWDP once a week for 13 weeks. Participants were divided into five groups of three to four learners per group. During this period the teacher followed the IWDP's instructional methodology. During the web design, action research allowed for the application of different instructional strategies, for example, scaffolding and modelling through cognitive apprenticeship.

3.4 Data collection methods

The teacher performed observations of learners' activities, events and learning processes. In her role as participant-as-observer, the teacher implemented the IWDP in the project-based classroom, conducted classroom observations and evaluated the impact of the programme on learning outcomes. The major aspects, the programme evaluation and outcomes (process and product) were evaluated. Learners expressed their experience of the IWDP in journals they wrote during and after each class. They wrote an essay to express their expectations of the course and the adaptation of instruction during action research. An independent researcher conducted the retrospective interview with the teacher, as well as a focus group interview with the learners

3.5 Analysis of data and assessment of trustworthiness

According to Merriam (1998), a constant comparative method within and between interviews is appropriate for qualitative data analysis. Multiple data-gathering methods (observations, interviews, journals, essays) and the use of two different data sources (teacher and learners) satisfied the criteria for methodological triangulation (Creswell 1994; Merriam 1998; Yin 1994). The data were consolidated and analysed through constant comparison of the data of the teacher's and learners' experience of the IWDP. Raw data were segmented into units that were comprised of chunks of a participant's speech or words. The units were coded in the margins of the interview transcripts, journals and field notes. Units from transcribed interviews were compared with units of actions, events and words recorded in field notes and journals. The researchers identified major themes and sub-themes or categories both within each interview transcription and across the observational notes (Merriam 1998). A 'map' of themes and a colour coding and reference number system was used to identify such themes.

The following measures were used for judging the validity of the research design: reliability, construct validity and internal validity (Creswell 1994; Merriam 1998; Yin 1994). Merriam's (1998, p.204, p.205) strategies, namely peer/colleague examination and the statement of the researcher's biases and Yin's (1994, p.33) conceptions about internal validity (making inferences, analytical pattern matching) were followed in this study. The former enhanced the internal validity of the findings. In addition, a rich, thick description of the researched phenomenon, which was embedded in a theoretical framework of learning theories, instructional models and strategies, contributes to the external validity of this study (Merriam, 1998, p.211). Instead of the limited generalizability of findings from the qualitative study, the intention was to form an interpretation of events (Merriam 1998, pp.207-210), based on uniqueness of the instructional environment. Strategies such as the statement of the researcher's biases, submerging the researcher in the study, making inferences and analytical pattern matching enhanced the internal validity of the findings in this study.

4 RESULTS

The following findings were made based on the interview and classroom observation that relate to the teacher's experience of the instructional methodology within the IWDP:

4.1 Findings regarding the teacher's experience of the instructional methodology

The following categories related to the teacher's experience of the IWDP were derived:

a) ***A pre-defined set of assessment criteria (AC), range statements (RS) and performance indicators (PI), learner activities and a variety of the teacher's actions relieved the teacher of the organisational burden of promoting a problem-solving atmosphere***
b) ***Technological stages provided an environment for explicit teaching of thinking skills and metacognitive strategies***
c) ***Practical and cognitive apprenticeship created a positive environment for technological problem solving***

The evidence and interpretation of the above categories are provided in the following paragraphs.

a) ***A pre-defined set of assessment criteria (AC), range statements (RS) and performance indicators (PI), learner activities and a variety of the teacher's actions relieved the teacher of the organisational burden of promoting a problem-solving atmosphere***

The teacher commented in the interview, *"… it was very important to have a structure [IWDP] consisting of tasks, activities, assessment criteria, performance indicators… as well as a variety of the teaching actions which helped me to organise the work and to lead them towards thinking…with the structured work learners had the feeling that they were being guided and had more time for research and solving the problem…".* Learners were given a map with a set of tasks and activities for each stage of the technological process (see Table 2). The teacher noted as follows, "*I thought that visual exposure to the tasks gave them direction during technological design. They were reflecting on previous tasks and activities, ticking off the completed activities, highlighting outstanding activities and adding new activities to suit their needs and skills..."*

The teacher commented in the observation protocol, "*the IWDP with its AC, RS and PI components and a variety of teacher strategies to choose from (for example, explanation, demonstration, modelling, questioning, discussions, dialogues, inquiry/investigation, lecture and whole-class instruction) relieved the organisational burden... rather than concentrating on organisational aspects (for example, setting learner tasks and activities for different stages of the technological process), the teacher spent time focusing on the facilitation of technological problem solving*".

The teacher furthermore observed, "*…activities were set to control the basic aspects of technological problem solving, starting with demonstrations of technological skills and providing a frequent modelling of thinking through a repetitive, cyclic mode of teaching. Learners were helped to construct and implement interviews, to write reflective notes and analyse documents and statistics relevant to the technological problem...*"

b) ***Technological stages provided an environment for explicit teaching of thinking skills and metacognitive strategies***

The teacher commented during the interview, "*I had to adapt teaching methods… thinking skills and reflective strategies were taught explicitly... It was useful to have technological stages… it was easier to address technological problem solving during technological stages. "*

The teacher commented in the observation protocol, "*learners enjoyed the teacher's modelling of thinking skills (for example, analysing a case with suitable questions and brainstorming techniques) and reflective thinking during the stages of the technological process... learners were very attentive, tried to imitate the pattern of thinking, by thinking loudly and asking corresponding questions about the problematic features of web design (how to analyse the problem, how to gather information)... learners were reflecting on their past experiences and demonstrating thinking skills to their peers, for example: "… wow, can I show my diagram … how can my functions fit into my map composition…?"*The teacher noted the following during the observation process, *"Thinking skills and their attributes were presented in the form of diagrams, pictures and semantic networks. Thinking skills were modelled and discussed with learners practising metacognitive strategies; and an active involvement in learning thinking skills provided a basis for technological problem solving…Learners often applied questioning during thoughtful dialogues in small, problem-solving groups… they brainstormed solutions for their web-design problems... they listened and watched team members' demonstrations of design features."*

c) Practical and cognitive apprenticeship created a positive environment for technological problem solving

The teacher reported that, "*learners helped each other… I was active with one group and then I would go to the next group… learners received help from project leaders, help from peers, from other groups.* "The teacher commented during the observation process, *"... expert-novice types of interactions were noted, for example, a higher achieving learner was assisting a less able learner through practical and cognitive apprenticeship [knowledge sharing]. I was acting as an expert demonstrating and modelling design activities through cognitive apprenticeship*."

The teacher observed, "*Peer-tutors demonstrated the design steps to members within their own group and to other groups. They expressed their feelings of enjoyment through body language, informal talk and comments such as "We have different skills and it helps to share knowledge in designing web site".* The teacher made comments in the observation – notebook, "*I felt that the instructional map allowed me to increase the frequency of interactions with learners such as: discussions, questioning, cognitive apprenticeship and the modelling of the system design features…"*

The following findings were made based on the focus group interview, journals and essays that relate to learners' experience of the instructional methodology within the IWDP:

4.2 Findings regarding learners' experience of the instructional methodology

The categories below are related to learners' experience of the IWDP:

d) ***Experiential and situated learning supported problem solving***

e) ***Step-by-step instruction in a peer-based collaborative learning environment supported problem solving***

f) ***Knowledge sharing within a network of experts and practical apprenticeship promotes technological design.***

The evidence and interpretation of the above categories are provided in the following paragraphs.

d) ***Experiential and situated learning supported problem solving***

Learners noted in the journal: "… o*nly in class there was somebody, right [the teacher] there, but when we met up on our own… we need more guidance… The teacher instructed us how to set agendas, how to participate in hands-on activities... and encouraged us to observe and interview sales people... ".* Learners commented during the interview: *"when you're designing a web page, there are a lot of tools that you can use to design it, we experienced a lot of things, and we had to interview managers...we found material on the internet, there are different applications that you can use. "*The teacher commented in the observation protocol, "*Learners searched the internet, magazines, books and brochures...They conducted interviews and observations in a real-world environment under the supervision of the teacher... ".*

e) ***Step-by-step instruction in a peer-based collaborative learning environment supported problem solving***

Learners reported in the journal, "*the developing software, it's a step-by-step process... you can't just start at one point and finish at a certain point...*

You have to keep things going a certain order...you have to see the whole process of design..."

Learners commented during the focus group interview, "*... it's taking less time to complete the step and then we can have less stress on everybody else… everyone in the group gives ideas and you build on the ideas together… George helped me with my design".*

f) ***Knowledge sharing within a network of experts and practical apprenticeship promoted technological design***

Learners commented in the journal, *"...You find that if we were working as individuals the stress would have been a whole lot more, but we were working as a group, we could divide what should be done in a certain step… the teacher helped us..."*

Knowledge sharing through practical apprenticeship and an active involvement in learning design provided a basis for technological problem solving.

5 DISCUSSION

From the evidence presented, as an answer to the *first research question,* the criteria for the IWDP laid a solid base for the facilitation of technological problem solving and provided a basis for a variety of learning modes and instructional strategies in the project-based classroom. From the results and in answer to *research question two,* in terms of the instructional methodology, the focus was on the following components of the IWDP: the stages of the technological process, AC, RS, PI, learner tasks and a variety of teacher activities.

The findings indicate that both innovative structure and the components of the IWDP were regarded as vital to assist the teacher in promoting technological problem solving. Through a set of pre-defined learner tasks and activities learners could develop implicit knowledge (procedural knowledge) (McCormick 1997: cited by Ankiewicz 2003, p.7). Through provisioning of a fully organised and structured learning and teaching environment via the innovative structure of the IWDP, learners could integrate conceptual and procedural knowledge more effectively (McCormick 1997).

Conclusions for the second research question were that provisions for technological problem solving *have* occurred in a few instances. For example, the teacher observed that AC, RS and PI and a variety of teacher strategies to choose from, relieved the teacher's organisational burden. Rather than concentrating on organisational aspects, the teacher spent time focusing on the facilitation of problem solving. However, the application of the instructional methodology in a different environment might be dependent on the competences and attitudes of the specific teacher. The findings show that there were various learning modes and instructional strategies to support learning. The fact that frequent use of practical and cognitive apprenticeship (Arzarello et al. 1993) has been widely accepted by learners indicates that various basic and advanced web-design skills were supported. The assumption is that the latter will eventually contribute to problem solving as this skill demands frequent interaction and knowledge sharing between expert and novice learners. Findings indicate that structured and sequential guidance can serve as an explicit instructional framework for both teacher and learner (McCormick 1994, McCormick 1997).

There was a need for explicit identification and a clear conception of thinking skills in a technology-based learning environment (Johnson 1997, p.172; Beyer 1991). Furthermore, small problem-solving groups and peer coaching through questioning, thoughtful dialogue, role play and reflection stimulated change in the structure of thinking (Wheatley 1991; Fogarty and McTighe 1993). Learners understood the idea of 'knowledge as design' through reflective activities (McCormick 1997; Winn 1990) as the findings indicate. Learners wanted to solve the problem; it was real and relevant to them. It is thus likely that learners can transfer these skills to other areas (McCormick et al. 1994, p.106). Based on the findings, it is reasonable to conclude that the innovative instructional methodology was based on constructivist and behaviourist instructional approaches that channelled learners' technological problem-solving skills during web-design activities.

7 CONCLUSIONS

In terms of the purpose of this study the following conclusions have been derived:

1. Criteria from learning theories, instructional models and strategies were derived as a point of the departure for the development of the IWDP.

2. The structure and related components for the IWDP were identified and described. The components that particularly positively influenced the problem-solving environment are as follows: A pre-defined set of AC, RS and PI, instructional strategies and learner tasks and activities relieved the teacher of the organisational aspects and provided the opportunity to concentrate on the facilitation of technological problem solving; technological stages provided an environment for problem solving and metacognitive strategies.

3. Key instructional strategies and learning modes were identified and discussed. The instructional methodology that both teacher and learners perceived as adequate for technological problem solving is:

   i. The use of peer-based learning and practical and cognitive apprenticeship stimulated the attainment of various basic and advanced web design skills and thinking.

   ii. Experiential and situated learning (a real-world problem with task-orientated teams) suited the dynamics and complex nature of learning and teaching in the ISD context.

   iii. The step-by-step instruction with explicit teaching of thinking skills and reflective strategies catered for both conceptual and procedural knowledge.

   iv. Knowledge sharing within a network of experts created a link between the IT technology classroom and the real-world environment and contributes to problem solving learning environment.

The complex structure and a variety of relevant components of the IWDP provided the teacher and learners with an organised and structured instructional and learning environment. This has some benefits for the teacher relieving the teacher from the organizational aspects and increasing the teacher’s energy and time for the facilitation of problem solving activities. Therefore, the IWDP provides an organized and structured instructional environment which could be applicable in a project-based classroom. Future research needs to be done into the application of the IWDP in different learning contexts. The implementation of an innovative instructional methodology within the IWDP revealed new paths in the facilitation of technological problem solving that could serve as a foundation for constructing an instructional web design model (IWDM).

8 REFERENCES

Ankiewicz, P., De Swardt, A.E., & Stark, R. (2000). *Principles, methods and techniques of Technology Education* I. Auckland Park: Rand Afrikaans University, RAU College for Education and Health (RAUCEH).

Ankiewicz, P.J., & De Swardt, A.E. (2002). Aspects to be taken into account when compiling learning programme to support effective facilitation of Technology Education. National Conference for Technology Teachers, Port Natal School, Durban, Conference Proceedings, 76-81, 30 September – 1 October 2002.

Ankiewicz, P. (2003). Technology education at school: Illusion or reality?: Inaugural address by PJ Ankiewicz, Rand Afrikaans University, Johannesburg, South Africa.

Arzarello, F., Chiappini, GP., Lemut, E., Marara, N., & Pellery, M. (1993). Learning programming as a cognitive apprenticeship through conflicts, In Lemut E., Du Boulay B and

Avison, D.E., & Fitzgerald, G. (1996). Information systems development methodologies: tools and techniques. Oxford: Blackwell.

Balfanz, R. (1991). Local knowledge, academic skills, and individual productivity: An alternative view. Educational Policy, 5(4): 341-370.

Baskerville, R.L., & Wood-Harper, A.T. (1996). A critical perspective on action research as a method for information system research. *Journal of Information Technology*, 11: 235-246.

Bednar, A.K., Cunningham, D., Duffy, T.M., & Perry, J.D. (1992). Theory into practice: How do we like? In Duffy M & Jonassen DH (eds), *Constructivism and the technology of instruction*: a conversation. Hillsdale NJ: Lawrence Erlbaum Associates Publishers.

Beyer, B.K. (1991). *Teaching thinking skills: A handbook for secondary school teachers.* Boston: Allyn & Bacon.

Boden, M. (1990). *The creative mind*. London: Weidenfeld & Nicolson.

Carver, SM., Lehrer R., Connell, T., & Erickson, J. (1992). Learning by hypermedia design: issues of assessment and implementation. *Educational Psychologist*, 27(3):385-404.

Castro, J., Kolp, M., & Mylopoulos, J. (2002). Towards requirements-driven information systems engineering: The Tropos project. *Information Systems*, 27(6): 365–389.

Cavan, S. (2007). Networking with other parties – developing strategic partnerships. Conference proceedings: International conference in educator lifelong learning, Kwazulu-Natal Education, Durban, South Africa.

Clark, C., & Lampert, M. (1986). The study of teacher thinking: implications for teacher education. *Journal of Teacher Education*, 37(5): 27-31.

Cotton, J. (1995). *The theory of learning strategies*. London: Kogan Page.

Creswell, J.W. (1994). *Research design: Qualitative and quantitative approaches*. California: Sage Publication, Inc.

De Bono, E. (1986). *CoRT thinking*. New York: Pergamon Press. Department of Education (1997). Outcomes Based Education in South Africa. Pretoria: DoE.

Dover, A. (1983). Computers and the gifted: Past, present and future. *Gifted Child Quarterly*, 27 (2): 7-11.

Eggen, P.D., & Kauchak, D.P. (1996). *Strategies for teachers: teaching content and thinking skills*. 3rd ed. Boston: Allyn & Bacon.

Duffy, J.S., & Cunnigham, D.J. (1997). Constructivism: Implications for the design and delivery of instruction. In David Jonassen eds. *Handbook of research in education, communication, and technology*. New York: Macmillan.

Elmer, R. (1998). Probing intentions of design and technology students. *International Journal of Technology and Design Education*, 8: 221-240.

Flynn, D. (1992). *Information Systems Requirements: Determination and analysis*. McGraw-Hill, Maidenhead.

Fogarty, R., & McTighe, J. (1993). Educating teachers for higher order thinking: the three-story intellect. *Theory Into Practice*, 32(3): 161-169.

Givens, N., & Barlex, D. (2001). The role of published material in curriculum development and implementation for secondary school design and technology in England and Wales. *International Journal of Technology and Design Education*, 11: 137-161.

Griffiths, G. (1998). *The essence of structured systems analysis techniques*. Prentice-Hall: Hemel Hempstead.

Hiltz, S.R. (1986). The virtual classroom: Using computer-mediated communication for university Teaching. *Journal of Communication*, 36(2): 95-104.

Jakovljevic, M. (2002). An instructional model for teaching complex thinking through web page design. DEd thesis. Rand Afrikaans University, Johannesburg, South Africa.

Jakovljevic, M., Ankiewicz, P., De Swardt, A.E., & Gross, E. (2004). A synergy between the technological process and a methodology for web design: Implications for technological problem solving. *International Journal of Technology and Design Education*, 14: 261-290.

Johnson, D, & Johnson, F. (1991). *Learning together and learning alone*. 3rd ed., Englewood Cliffs, NJ: Prentice-Hall.

Johnson, S.D. (1997). Learning technological concepts and developing intellectual skills. *International Journal of Technology and Design Education*, 7: 161-180.

Jonassen, D.H. (1996). *Computers in the classroom: mind tools for critical thinking*. New Jersey: Prentice-Hall.

Jonassen, D.H., Beissner, K., & Yacci, M.A. (1993). Structural knowledge: techniques for assessing, conveying and acquiring structural knowledge. Hillsdale NJ: Lawrence Erlbaum Associates.

Jones, A. (1997). Recent research in learning technological concepts and processes. *International Journal of Technology and Design Education*, 7: 83-96.

Kolb, D.A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs NJ: Prentice-Hall.

Leedy, P.D., & Ormrod, J.E. (2005). *Practical research: planning and design*. New Jersey: Pearson Education.

Mabrito, M. (1992). Computer-mediated communication and high apprehensive writers: Rethinking the collaborative process. *Bulletin of the Association for Business Communication,* 55 (4): 26-29.
Magadla, L. (1996). Constructivism: a practitioner's perspective. *Sajhe/Satho,* 10(1): 83-88.
Marzano, R.J., Brandt, R.S., Hughes, C.S., Jones, B.F., Presseisen, B.Z., Rankin, S.C., & Suthor, C (1988). Dimensions of thinking: A framework for curriculum and instruction. *Association for supervision and curriculum development*. Alexandra: Reston VA.
McCormick, R. (1997). Conceptual and procedural knowledge. *International Journal of Technology and Design Education,* 7: 141-159.
Merriam, S.B. (1988). *Case study research in education: a qualitative approach*. San Francisco: Jossey-Bass.
Patton, M.Q. (1980). *Qualitative evaluation methods*. Beverly Hills CA: Sage Publications.
Perkins, D.N. (1994). *Knowledge as design: A handbook for critical and creative discussions across the curriculum*. Pacific Grove: Critical thinking Press and Software.
Pfleeger, S.L. (2001). *Software Engineering: Theory and Practice, second edition*. Englewood Cliffs NJ: Prentice-Hall.
Pressman, R.S. (2005). *Software Engineering: A Practitioner's Approach, sixth edition.* Singapore: McGraw-Hill.
Rogoff, B., & Lave, J. (1984). *Everyday cognition: its development in social context*. Cambridge Mass: Harvard University Press.
Simons, P.R.J. (1993). Constructive learning: the role of learner. In Duffy T., Lowyck J & Smallwood, J. (1995). Technology discussion in the classroom. In Edmision GA. Delivery systems: Instructional strategies for Technology Education. *International Technology Education Association (ITEA)*: Reston VA, (pp.5-6).
South Africa (1997, 6). Government Gazette, Pretoria: DoE.
Van Niekerk, E., Ankiewicz, P., & De Swardt, E. (2010). A process-based assessment framework for technology education: A case study. *International Journal of Technology and Design Education,* 20(2): 191-215.
Wheatley, G.H. (1991). Constructivist perspectives on science and mathematics learning. *Science Education,* 75(1): 9-21.
Winn, W. (1990). Some implications of cognitive theory for instructional design. *Instructional Science,* 19: 53-69.
Yin, R.K. (1994). Case study research: design and methods. *Thousand Oaks,* California: Sage Publications.

Acknowledgements
I would like to express my sincere gratitude to my co-supervisor **Prof. Estelle De Swardt** for the continuous support of my doctoral study.