

A Shift from Traditional Teaching to the Development of Complex Thinking in a Technology Classroom in South Africa

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Abstract: Traditional teaching in technology classrooms failed to concentrate on the new technologies conducive to the development of the in-depth understanding of design concepts and procedures of an information system. Thus the needs of learners in technology classrooms were neglected, concentrating mainly on low-level thinking. The purpose of this paper is to explore the impact of web technology in shifting from the traditional way of teaching to the development of learners' complex thinking in the technology classroom. This research was based on a qualitative, action-research approach in which individual interviews, focus group interviews, observation and documents were used to gather data (Yin 1994; Merriam 1998). A total of 17 students at an institution of higher education were observed and their experiences were investigated through a focus group interview, journals and essays. The findings of this study reveal the necessity for explicit teaching of complex thinking through Internet technologies and the collaboration with the business world in order to promote the teaching of thinking skills. Findings indicate a need for a design of information systems to be used in conjunction with practical and cognitive apprenticeships. This will enlarge and strengthen the insight into the technological design and set a learning environment conducive to thinking.

Keywords: web technology, complex thinking, technology education

INTRODUCTION

Traditional teaching in a technology classroom was not suitable for the development of thinking skills because it did not raise the learners' awareness of the importance of reflecting on thinking processes while exploring a variety of design solutions (Balfanz 1991; Johnson 1997). The current focus in technology classrooms is moving towards facilitating thinking skills and concentrating on activity-based practice (Johnson, 1997). In the relevant literature (for example, Winn 1990; Bednar, Cunningham, Duffy & Perry 1992) there is a remarkable absence of discussion on explicit facilitation of a wide range of thinking skills that learners should develop in a technology classroom. 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). In the past it was not clear how complex thinking could be integrated through existing technologies in a technology classroom. One of the possible ways was to teach complex thinking explicitly through the guidance of a network of human resources and an expert-mentor relationship (Jakovljevic 2002). This could make learners aware of their thinking processes, promoting their responsibilities and monitoring the understanding of their own thinking processes. Learners should discuss the topic with either a tutor or experts (Laurillard 1994; Schon 1987).

It is generally accepted that sequential processing of information during design activities in technology classrooms results in the overloading of learners' information processing capabilities. In addition to knowing design concepts (declarative knowledge) learners must form plans, solve problems and make decisions (procedural knowledge) (McCormick 1997).

Traditional teaching in technology classrooms failed to concentrate on the new technologies conducive to the development of in-depth understanding of design concepts and procedures of an information system (Johnson, 1997; Jakovljevic, 2002). Learners were not exposed to the real-world environment, for example, solving business problems using web technology, which created little opportunity to utilise their own experience and complex thinking (Jakovljevic, 2002). The thinking needs of learners in technology classrooms were neglected, concentrating mainly on low-level thinking.

Problem solving is enhanced through learners attempting 'real world' technological problems, because design and technology rely heavily on experience (Shield, 1996). The mastering of complex thinking skills by means of Internet technology in a real-world environment has been a crucial need in a technology classroom. A shift from traditional teaching (low-level thinking) to the development of complex thinking must be made. The purpose of this paper is to explore the impact of web technology

in shifting from the traditional way of teaching to the development of learners' complex thinking in the technology classroom.

The research questions addressed in this paper are:

1. How can the explicit teaching of thinking be incorporated in the technology classroom using web technology?
2. What human resources are required to teach learners information systems design concepts and techniques?
3. What is the role of project work in the use of new technologies?

In considering these questions, the researcher argues for more emphasis on in-depth research concerning human resources, the use of Internet technologies, innovative strategies in promoting complex thinking and a new perspective on project work in the technology classroom.

THEORETICAL FRAMEWORK FOR TEACHING COMPLEX THINKING IN A TECHNOLOGY CLASSROOM

Foundation underlying a shift in teaching of complex thinking

The new Outcomes-Based Education (OBE) school curriculum in South Africa is aimed at developing creative problem-solving skills in every learning area (DoE 1997a; South Africa 1997; SAQA 1997). OBE focuses, amongst others, on critical thinking, effective communication, and problem-solving (Jakovljevic 2002). In addition, policy related to Technology Education; the conceptions of the Illustrative Learning Programme (DoE 1999); clear description of the ten stages of the technological process (Ankiewicz, de Swardt & Stark 2000) and the roles and competencies of the teacher in a technology classroom serve as the further foundations that underlie the shift in teaching in the technology classroom (Jakovljevic 2002). Policy related to Outcomes-Based Education and Technology Education in South Africa highlights the necessity to meet the critical learning outcomes and specific learning outcomes (South Africa 1997; DoE 1997b) in the technology classroom.

Technology can be regarded both as 'minds-on' (complex thinking) and as 'hands-on' (practical activities) (McCormick & Davidson 1996; Ankiewicz 2003). This foundation influenced the change in teaching and learning environment in technology classrooms. Technology classrooms have changed, becoming real constructivist classrooms that provide the freedom for learners to find alternative solutions and to reflect on learning.

The role of project work in a technology classroom: Linking real-world business practice into a technology classroom

Technology Education should, in its deepest nature, also be project-based and constructivist, paving the way for truly Outcomes-Based Education (OBE) (Ankiewicz 2003). Therefore, the project-based nature of technology is vital when learners are involved in designing information systems. Learners have to find solutions to a real-world problem that is relevant to their experience (McCormick, Murphy & Hennessy 1994). Jonassen (1996) suggests the need for real-world problems that promote learners' motivation, thinking skills, enthusiasm and creativity. Encouraging learners to find a solution to the identified real-world problem in the form of a web site and communicate with the business world exposes them to a situational and problem-solving learning context.

Project work in the technology classroom has changed, encouraging practical and cognitive apprenticeship, peer-based learning and creative involvement of the teacher (Eggen & Kauchak 1996). An interaction between a technology expert and novice is aimed at enhancing the cognitive and meta-cognitive skills of learners (Arzarello, Chiappini, Lemut, Marara & Pellery 1993).

a) Task focused teams in a technology classroom

Project teams consist of small number of team members with complementary, mutually accountable skills, committed to a common purpose. A project team should form a virtual company, linking a real-world business environment to the technology classroom, which excites and motivates learners. It enables progress and measurement of project objectives.

The learning climate of task-focused teams in the technology classroom has to be carefully monitored to promote passion, stamina and freedom and to operate with innovative ideas. Teams should have clear performance goals, with parallel non-sequential tasks, with the aim to coordinate cross-functionality, and build an achievement culture. Teams should set a defined strategy and operations based on a real-world business environment, promoting a climate of learning led by the questions what? why? how? where? Team members should be taught to have a positive attitude, to communicate in a wide human environment, to deal with processes of problem-solving and to be deeply involved in planning. Research supports collaborative work in both educational and corporate settings (Jonassen 1996; Harel & Papert 1990).

Task-focused teams working with new technologies should have a vision, should be collaborative and enthusiastic. They should appropriately manage their perceptions. Through instilling basic beliefs into their hearts, heads and hands they must be taught how to achieve balance and perspective in developing solutions to real-world problems. Teams must be taught how to measure performance, such as cost-effectiveness, efficiency and effectiveness.

b) Use of web technology and mind tools in a technology classroom

In the new technology classrooms learners are involved with web technologies supported by diverse mind tools (for example, concept mapping and computer mediated communication (CMC)). Mind tools are computer tools that are intended to engage and facilitate cognitive processing of learners (Kommers, Jonassen & Mayes 1992; Jonassen 1996). Computer mediated communication (CMC) acts as a vehicle for delivering and sharing the product of any mind tool (Jonassen 1996). Vision as the most powerful human sense (Boden 1990) can be promoted by integrating mind tools in a technology classroom.

Concept maps are special representations of ideas and their interrelationships within the human memory structure (Jonassen, Beissner & Yacci 1993; Jonassen 1996). Concept mapping supports deductive learning (James & Gardner 1995). This can satisfy the 'association of contiguity' (Mayer 1992) by involving learners in creating links between concepts in the visual field.

An extended human network in a technology classroom

The fact that experts have different structural knowledge compared to novice learners (Jonassen et al. 1993) implies that they can model their expert knowledge, which may enhance learners' knowledge structure, in a technology classroom. Experts can be involved in a technology classroom through practical and cognitive apprenticeship. Cognitive apprenticeship is an interaction between an expert and a novice aimed at enhancing the cognitive and meta-cognitive skills of learners (Arzarello, et al. 1993). Practical apprenticeship is aimed at reproducing, possibly with some changes, actions from a model usually given by an expert. An extended human network is empowered through practical and cognitive apprenticeship, which supports experiential learning (Kolb 1984).

A shift from low-level thinking to complex thinking in the technology classroom

To achieve effectiveness in the facilitation of complex thinking in the technology classroom the teacher must be familiar with the thinking processes and skills in general (Jakovljevic 2003). The ability to monitor our own understanding, and to plan and evaluate our own learning strategies is an essential prerequisite for problem-solving and intellectual skills in general (Johnson 1997).

Defining thinking skills and their attributes (Beyer 1991) and communicating these to the learner enhance teaching of complex thinking. Explicit teaching of thinking skills allows learners to monitor their own thinking processes (Jones 1997).

According to Beyer (1991) each thinking skill consists of attributes such as: a procedure (a series of the steps and sub-steps); a rule or principle (which informs and guides the execution and application of the procedures); and criteria of other knowledge (applied in executing the procedure or following the rules). In the context of web design, where design skills are essential, a clear model of design skills and their attributes are required. 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 their use, and what to do when the skill does not work" (Beyer 1991).

The process of modeling should not be ignored during the development of design and thinking skills (Welch 1998). Thus, learners should communicate design procedures to themselves and to other members of a design team (McCormick et al. 1994). Social support for creative activities undoubtedly plays a crucial role in the technology classroom.

A shift from low-level thinking to complex thinking in the technology classroom is possible by recognising the importance of learners' research skills (Harris 1999), the importance of learners' real experience (Shield 1996), learners' own problem-solving abilities (Jonassen 1988), concrete representation of problems (Meyer 1992), modelling (McCormick et al. 1994) and informal problem-solving procedures (McCormick, Murphy & Hennessy 1994).

Based on the literature it seems that the following aspects could influence a shift from traditional teaching to the creation of positive thinking atmosphere in the technology classroom:

- A new perspective on project work and task-focused teams
- Explicit teaching of thinking skills with Internet technologies and diverse mind-tools

- An extended human network and collaboration with the business world .

RESEARCH DESIGN

This research can be described as a qualitative, single case study where action research was applied to investigate and create changes during web page design (Creswell 1994; Yin 1994; Merriam 1998).

Method of sampling

Purposive sampling involves the selection of information-rich cases for in-depth study (Patton, 1980). In this study convenience sampling as a particular type of purposive sampling was applied (Merriam, 1998). In convenience sampling a sample is selected on the basis of time, money, location, and availability of respondents (Patton, 1980). The purpose of choosing a small non-random sample was based on the researcher's wishes to understand the phenomenon in depth (Merriam, 1998).

Two distinct mixed cultural groups of learners were identified. These consisted of five second-year learners (2 females and 3 males – average age of 20) enrolled for the Information Systems Diploma and 12 first-year learners (5 females and 7 males – average age of 19) enrolled for the International Diploma in Computer Studies at a Higher Education Institution. Learners from the first group came from a middle socio-economic background. Most of the learners from the second group were from under developed socio-economic background.

Setting

The researcher of this study developed and facilitated the Instructional Web Design Programme (IWDP), as an extra-curricular programme in a well-equipped computer centre at a university to a group of seventeen learners (Jakovljevic 2002).

The computer centre is equipped with three rows of computers. The centre has one assistant desk with the computer placed in the corner and a printer. The fax/copier machine and scanner are placed in another corner of the centre. In the middle of the room is an overhead projector with a crystal display unit facing a white board and display wall unit. The light can be dimmed. Microsoft architecture and technologies are provided in the setting.

The purpose of the IWDP was to have an impact on the technological problem-solving and web design skills of learners in the project-based classroom. The IWDP was presented once a week for 13 weeks, with duration of four hours per session (Jakovljevic, Ankiewicz & de Swardt 2004).

Learners were expected to develop a solution to the business problem in the form of a web site. Building an information system as a solution to the business problem, namely 'car purchasing schemes', using web technology, learners could utilise their own experience and complex thinking by linking the technology classroom to the real-world environment.

The learning outcomes, mode of teaching and assessment of the IWDP

In this study diverse instructional strategies and learning modes based on constructivism and behaviourism were applied (for example, direct teaching, practical and cognitive apprenticeship, group discussions, experiential learning, collaborative learning, discovery learning, and observational learning).

The teacher clearly communicated critical and specific learning outcomes to the learners. Critical outcomes as generic cross-curriculum outcomes are essential for assessing learners' attainment of cognitive outcomes, which influence their own success and contribute to a wider community. Specific outcomes include technological knowledge, skills, attitudes and values that help learners to understand and demonstrate achievements in technological contexts (DoE, 1996).

Learners' design teams were assessed through observations and continuous assessment and monitoring of learners' performance using a progress chart and identifying:

- the level of innovation and exploration
- learners' contributions to explanations of the principles of web design issues
- the extent to which the project-based classroom has become a design community.

Data collection and analysis

Data were gathered through multiple data gathering methods which satisfy the criteria for triangulation (Creswell 1994; Yin 1994; Merriam 1998). The teacher conducted the classroom observations, which relates to an extensive description of the teacher's actions, thoughts and feelings related to instructional strategies, events, words and interactions of learners in the project-based classroom. Learners

expressed their experience of web page design through journals.

An experienced interviewer conducted the retrospective interview with the teacher and a focus group interview with the learners. The interviewer possessed some degree of familiarity with the phenomenon and the setting under study, as well as extensive experience in the coding process and analysis of qualitative data.

Open-ended interviews were conducted using interview protocols and probing questions. Interviews were recorded using a tape recorder. Taped interviews were transcribed verbatim. In addition, the independent researcher recorded the reflections (by writing descriptive notes on verbal and nonverbal behaviour) immediately following the interview. The constant comparative method was applied to the data within and between interviews (Merriam 1998).

Reliability or consistency, construct validity, internal validity or credibility and external validity were used for ensuring the trustworthiness of the research (Yin, 1994; Merriam, 1998). This study is characterised by the use of two different data sources (the teacher and learners), multiple data gathering methods (triangulation) and case study protocols.

FINDINGS

The following paragraphs present findings of the teacher and learners with regard to teaching and learning in the technology classroom. The following categories were derived:

- a) Explicit teaching of thinking and its attributes influences learners' awareness of their own thinking skills while using web technology
- b) A network of human resources (teacher, assistants and peer-tutors) is crucial for the teaching of complex thinking in the technology classroom
- c) Project work simulates a real-world business environment
- d) Employing practical and cognitive apprenticeship in task-focused teams contribute to learning thinking skills
- e) The expert guidance from the teacher, assistants and peer-tutors widens learners' understanding of new technologies

Findings regarding the teacher's experience in teaching complex thinking

Emerging from the interview and classroom observations relating to the teacher's experience of facilitating web design, the following findings were made:

a) *Explicit teaching of thinking and its attributes influences learners' awareness of their own thinking skills while using web technology*

The teacher noted , “ *I thought that visual representation of thinking skills gave them an awareness... They were reflecting, talking, leaning forward during demonstration and modelling of thinking skills.*” The teacher commented: “*I had to adapt teaching methods...thinking skills and reflective strategies were taught explicitly...*”

The teacher also noted in the observation protocol, “*learners enjoyed modelling of thinking skills, taking an active role in demonstrating thinking strategies to their team members*”. The teacher further noted, “*learners were interested when thinking skills were presented in a graphic form...*”

Taking an active role in advancing their thinking skills, learners developed the responsibility to monitor their level of thinking during web design. They had opportunities to build their thinking skills in a variety of real-life situations. Being exposed to the explicit teaching of thinking learners developed awareness of the gaps in their thinking strategies relevant to the web design context.

b) *A network of human resources (teacher, assistants and peer-tutors) is crucial for the teaching of complex thinking in the technology classroom*

Creating a positive environment for teaching complex thinking is possible, if a network of human resources (teacher, a senior tutor, peer-tutors, an assistant, technical assistant) is provided in the technology classroom. By handing over practical responsibilities to a teaching assistant, technical assistant and peer-tutors, the teacher is provided with more time to be involved in teaching complex thinking. The support is expected from a teaching/administrative assistant who could relieve the teacher of the organizational burden.

The teacher felt that an extended human network relieved her of her organisational burden, benefiting her effort to focus on the facilitation of complex thinking. The teacher reported that: “*students helped each other ...I was active with one group and then I would go to the next group... learners experienced help from the project leaders, help from peers, from other groups.*”

An expert-novice type of interaction was observed between learners, peer-tutors and an assistant. The teacher noted, “*A teaching assistant was often interacting with project teams explaining web design issues and demonstrating programming code. Peer-tutors acted as experts modelling and demonstrating web programming*”. The observations indicated that a human network was essential in the technology classroom.

c) Project work simulates a real-world business environment

The teacher noted, “*They were immersed in designing a web product... They were ready to continue the work at home*”. Observations revealed that simulating project work in a real-world business environment contributed to higher efficiency in web design, and to enjoyment and dedication of learners to project tasks. Learners were motivated as they were involved in building their real-world business experience by producing a web product in phases, similar to real-world projects.

The teacher observed that promoting an atmosphere of reflection and questioning based on what, why, how and where questions resulted in more frequent questioning amongst learners in project-teams.

Findings regarding learners’ experience of learning web design

The following deductions were made regarding the learning experience of web design in the technology classroom:

d) Employing practical and cognitive apprenticeship in a task-focused team contributes to learning thinking skills

Learners commented that: “you find that if we were working as individuals the stress would have been a whole lot more ...everyone in the group gives ideas and you build on the ideas together...”

It was observed that task-focused teams reflected a right attitude to getting things done and were involved in an open and honest debate during web design. It was observed that peers, a teaching assistant and the teacher modelled the positive behaviour and cultivated a positive thinking atmosphere, which could influence learners’ attitude towards project work.

According to learners’ notes in the journals they were exposed to apprenticeship learning in a wide human environment dealing with processes of problem-solving and planning: “*...the manager and the sales representative helped us...now I understand the problem...*” The teacher observed that,

“the learners in both groups welcomed the real-world nature of the problem by expressing the enjoyment in allocated tasks such as interviewing sales and marketing personnel in companies”.

e) The expert guidance from the teacher, assistants and peer-tutors broadens learners’ understanding of new technologies

The teacher noted *“Learners discussed web design aspects with their peers and the assistant... they were thinking aloud, reflecting on past experiences and discussing web design issues with a teaching assistant”*. The observations and journals notes revealed that learners were actively involved in the collaborations with the extended human network. Due to the complex nature of the technological design, interactions with the technology teacher were not sufficient. The comments from the assistant were noted in the teacher’s observation protocol: *“... I have to talk to many groups ...they ask many questions at the same time ...”*. It was observed that the expert guidance from the peer-tutors and the assistant in the technology classroom helped learners in advancing web technologies.

DISCUSSION

From the results, and as an answer to the first research question, explicit teaching of complex thinking was applied, incorporating creative instructional strategies (for example: step-by-step instruction, explicit teaching of thinking skills, peer-based teaching, cognitive and practical apprenticeship, guided discovery approach, reflective practice) as well as a variety of online tools (mind-tools) and techniques. Beyers’ (1991) ideas on thinking skills and their attributes (a procedure, the rule or principle, criteria) were considered essential for promoting learners’ self-awareness and for controlling and monitoring their thinking processes, which form instruction in a technology classroom.

Involving a network of experts in the field created a link between the technology classroom and the real-world environment, contributing to teaching of complex thinking (as an answer to the second research question). With inadequate technological knowledge, learners need modelling, coaching and scaffolding (Johnson 1997) in order to develop complex thinking. Due to the complexity of design issues in the technology classroom the additional human resources are necessary particularly when dealing with administrative tasks and new web technologies.

Motivating learners to use web technology in developing their product as a solution to a real business problem contributed to effective teaching of complex thinking in technology classrooms

(as an answer to the third research question). Developing a solution to a real business problem through project work help learners to consolidate the knowledge and skills what they have learnt in the IWDP and link the technology classroom to the real-world learning environment. Jonassen (1996) suggests the need for real-world problems that promote learners' motivation, thinking skills, enthusiasm and creativity.

Teaching technology assumes the use of different instructional strategies and learning approaches based on constructivism and behaviourism, which will extend learners' cognitive capabilities. Teaching technology could extend learners' procedural knowledge by promoting structured conceptual knowledge (Diekhoff 1983; Jonassen 1996; McCormick 1997).

CONCLUSION

Based on the findings of this research and the accepted standards in technology education in South Africa, a shift in teaching in the technology classroom, from low-level to complex thinking, should include the following:

- practical and cognitive apprenticeship within an extended human network (a teaching assistant, a technical assistant, peer-tutors).
- Explicit teaching of thinking skills and their attributes, which suit the dynamic and complex nature of web design technologies.
- A real-world business environment with task-orientated project teams as well as an innovative insight into project team dynamics, settings and attitudes.

It has been shown, in this study, that the role of design project work and the use of Internet technologies in technology classrooms, have been extended, encompassing new trends in teaching such as creating a wide mentorship network in the business environment.

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