Grade 9 Technology teachers' explication of critical thinking and its enactment in the classroom

Malose Kola[1*], Willem Rauscher[2] and Grietjie Haupt[2]

[1]University of Limpopo, South Africa; [2]University of Pretoria, South Africa

*Corresponding author Malose Kola: malosekola@yahoo.com

Abstract

The South African Curriculum and Assessment Policy Statement (CAPS) for technology stipulates that technology should provide learners with the opportunity to solve authentic problems that are embedded in real-life experiences. Solving these authentic technological problems requires learners to use critical thinking skills and teachers are expected to support learners in this regard. Questions around teachers' perspectives of what constitutes critical thinking and their ability to support the development of critical thinking skills in technology classrooms are rarely asked. It is in this regard that this study sought to explore Grade 9 technology teachers' understanding of critical thinking and how they develop critical thinking skills in their classrooms through the use of a mini- Practical Assessment Tasks (mini-PAT). The study applied a multiple case study design, in which a literal replication strategy was used to identify consistent patterns of description of the six participants' understanding and enactment of critical thinking in practice. Facione's framework for critical thinking was used to guide the analysis of interview and classroom observational data for various stages of the design process. The participants' understanding of the notion critical thinking brought about four conceptions of critical thinking skills, namely interpretation, analysis, evaluation, and inference. The results of the study show that there is a huge discrepancy between what technology teachers *say* and what they *do* in reality, highlighting the difficulty of translating and employing critical thinking skills in the classroom setting.

Key words: Analysis; critical thinking skills; interpretation; evaluation; inference

Introduction

Rapid technological changes together with the changes in the work environment have made *critical thinking* more important than ever (Ku, 2009). As a desirable human trait, critical thinking is increasingly recognised as an educational goal (Hitchcock, 2018; Facione, 2015; Mulnix, 2012; Siegel, 2010). According to Duran and Sendaĝ (2012) it is essential that learners are taught skills, such as investigating, analysing information, and reflecting, because they are vital for the development of their critical thinking ability. Thus, opportunities for learners to acquire and use critical thinking skills should be introduced into schools (McPeck, 2017; Siegel, 2010). The significance of including critical thinking in educational contexts lies in its ability to "allow individuals to go beyond simply retaining information, to actually gaining a more complex understanding of the information being presented to them" (Dwyer, Hogan & Stewart, 2014, p. 44). Ku (2009) asserts that it is important to teach critical thinking, since learners need to develop reasoning capacities that are essential in a rapidly changing world. Yang and Chou (2008) note that teaching learners to think critically is important because critical thinking is a fundamental skill required in the workplace for decision making, leadership, scientific judgement, thus leading to professional success and reflective participation in society.

The South African Department of Basic Education (DBE) introduced technology into the Senior Phase (Grades 7-9) of the school curriculum because of the need to produce engineers, technicians, and artisans, whose skills are in demand in modern society (DBE, 2011). Technology should, according to the DBE (2011), inspire learners to be creative and to develop the critical thinking skills required for success in a technology-driven world. The scope of technology education specifies that learners should be provided with opportunities to learn through applying various skills that are pertinent to real life situations and authentic contexts (DBE, 2011). These skills include the ability to think critically and innovatively; work in partnership; be able to identify needs; and solve problems using the design process (DBE, 2011).

The current learning activities in the technology classroom place a great deal of emphasis on the acquisition of facts, rules and action sequences by learners, which demand lower-order thinking skills (Lombard & Grosser, 2008). Reed and Kromrey (2001) claim that even after spending many years in the education system, most learners lack critical thinking skills. Haas and Keeley (1998) agree and point out that the emphasis in technology teaching is often placed on developing content knowledge. Makina (2010) highlights the fact that teachers are productive in presenting content knowledge, but not effective in enacting critical thinking skills. Pitchers and Soden (2000) add that teachers are not trained to instil critical thinking skills in learners and, as a result, teachers are not clear on what is expected of them in order to develop critical thinking skills of learners.

A study conducted by Lombard and Grosser (2008) discovered very little evidence concerning the advancement of critical thinking skills at the school level. Instead, teaching in the technology classroom is restricted to lower-order thinking, such as remembering, understanding, and applying (Mathumbu, Rauscher & Braun, 2014). It is therefore not surprising that the study conducted by Grosser and Nel (2013), who used the Watson Glaser Critical Thinking Appraisal (WGCTA) instrument to measure critical thinking skills of a heterogeneous group of 117 first-year Bachelor of Education (B Ed) students, revealed that South African freshmen struggle to demonstrate inference and interpretation skills. The findings of these research reports are problematic and a cause for concern. Mathumbu et al. (2014) emphasise that, if learners are not supported to develop higher-order thinking skills, the aims of technology education are not accomplished, and this may have implications for further studies. The purpose of this study was, thus, to investigate how technology teachers explicate critical thinking and actualise it in their classrooms. The following research questions were addressed:

- What is the technology teacher's understanding of the notion of critical thinking?
- How do technology teachers promote critical thinking in their classroom?

Critical thinking

The notion 'critical thinking' was conceptualised by John Dewey, who referred to it as 'reflective thinking'. Dewey (1910, p. 6) defined critical thinking as "an active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends". However, the term 'critical' originates from the Latin word *'criticus'* which means critic. To be critical means to analyse and evaluate a matter in order to build a sound judgement. In this spirit, Facione

(2015, p. 27) defines critical thinking as "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based".

Critical thinking skills

Halpern (2014, p.8) describes critical thinking as "the use of those cognitive skills or strategies that increase the probability of a desirable outcome. It is used to describe thinking that is purposeful, reasoned, and goal directed – the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions". However, according to Facione (1990, p. 28) a critical thinking skill, just like any other skill, is the potential to engage in an activity, process or procedure. Basically, a person who has acquired a skill is able to do the right thing at the right time. Being skilful includes having some degree of proficiency in implementing specific procedures, and a keenness to do so, at the opportune time. Moreover, to reflect on and improve one's critical thinking skills includes judging whether one is carrying out the task successfully or not, and to possibly consider different techniques to improve the enactment. Facione (1990) emphasizes the fact that cognitive skills, such as critical thinking, can be taught using various methods, such as ensuring that the process is clear, describing how the process is to be applied and implemented, explaining and showing the correct use, and justifying the application.

This study utilised classification of essential critical thinking skills and sub-skills as identified by Facione (2015) as a guide. Sub-skills are basic skills that constitute the main skill. For instance, interpretation is substantiated by the learner's ability to categorise, decode and clarify the meaning of information. Table 1 provides a summary of these critical thinking skills and sub-skills. The skills outlined in the table were used as a benchmark to determine how technology teachers explicate critical thinking and its enactment in the classroom.

Table 1: Essential critical thinking skills (Facione, 2015)

Skills	Sub-skills
Interpretation	Categorisation Decoding significance Clarifying meaning
Analysis	Examining ideas Identifying arguments Analysing arguments
Evaluation	Assessing claims Assessing arguments
Inference	Querying evidence Imaginingalternatives Drawing conclusions
Explanation	Stating results Justifying the procedure Presenting arguments
Self-regulation	Self-examination Self-correction

According to Facione (2015), interpretation (Table 1) refers to the competency of being able to understand and effectively articulate meaning and the implications of experiences, circumstances, information, beliefs, criteria, and processes over a broad scope of contexts. Analysis refers to the ability to recognise the intended and substantial conclusive relationships between assertions, questions, notions, narratives, which aim to, *inter alia*, articulate certain beliefs or experiences. Evaluation involves the ability to assess the trustworthiness of information that represents an individual's perspective, experience, circumstances, and conviction. Inference involves the ability to recognise and ascertain elements required to, *inter alia*, reach a reasonable conclusion; form hypotheses; and consider appropriate information. Explanation refers to the capacity to present results precisely and defend those results using predetermined criteria. Self-regulation means the competency to observe one's cognitive conduct, including elements that were applied in activities and how results were obtained.

The next section presents the design process, which is regarded as the backbone for teaching technology in South Africa (DBE, 2011). One of the fundamental goals of teaching the design process is to promote the development of cognitive skills that are essential for solving technological problems (Mioduser & Dagan, 2007). The design process provides learners with an opportunity to investigate, design, make, evaluate, and communicate as they solve the technological problem. This process requires learners to apply critical thinking skills in every phase of the design process. CAPS (DBE, 2011) emphasises that the design process is cyclical and driven by evaluation in every phase.

Design process

Design and problem solving are fundamental aspects of both technology and technology education (Potter, 2013). Opportunities to solve authentic problems using the design process and to engage critical thinking skills in the South African technology curriculum are provided through Mini-Practical Assessment Tasks (mini-PAT). A mini-PAT (see Appendix A) is a set of short practical assessment tasks that make up the main formal assessment of learners' skills and their application of knowledge during each term (DBE, 2011). Technology education in South Africa consists of four core contents that are compulsory for Grades 7-9. The content involves (a) structures, (b) processing, (c) mechanical systems and control, and (d) electrical system and control. Four mini-PAT activities are undertaken, focusing each on one core content area.

Table 2 presents the design process and the associated activities required to solve given design problems in the mini-PAT. For instance, during the first term, Grade 9 learners focus on structures, and address only three phases of the design process, namely, communicate, design, and make. In the final term, as learners focus on processing, emphasis is placed on design and make.

Table 2: Design process (DBE, 2011)

The process	Activities
Investigation	Seek information Conduct relevant investigation Grasp concepts and gain insight Determine new techniques
Design	Design brief Generate possible solutions Draw ideas Graphics (2/3D) Choose best solution and justify
Make	Use tools and equipment Building, testing, and modifying product Safety and health atmosphere
Evaluate	Evaluate actions, decisions, and results Evaluate solutions and the process followed Suggest necessary improvements Evaluate constraints
Communicate	Presentation Record of process

Design is an essential cognitive activity that involves solving problems that are ill-structured (Visser, 2009; Jonassen, 2011; Goldschmidt & Rodgers, 2013). Table 2 illustrates the nature of activities that learners focus on as they apply the design process. For instance, investigation involves seeking information and conducting the relevant research. Design, as the second phase of the design process, requires learners to, *inter alia*, sketch a design brief, generate possible solutions, and draw their ideas. The third aspect of the design process, make, provides learners with opportunities to use the tools and equipment. After finding a solution, learners evaluate their actions, decisions, results, and suggest necessary improvements. Lastly, during communication, learners are required to present the solution and explain and justify the process that has been followed from conception to realisation of the solution. The process involves the ability to analyse, investigate, plan, design, draw, evaluate, and communicate (DBE, 2011).

Methodology

Research approach

This study used the qualitative approach of a multiple case study, i.e. several case studies were used to further understand and investigate a particular phenomenon (Ary, Jacobs & Sorensen, 2010). A single case may not provide a thorough understanding of the phenomenon being investigated. Using multiple cases can, thus, provide better insights into how teachers explicate and actualise critical thinking skills. Permission to conduct the study was obtained from the Limpopo Department of Education, as well as from the principals of the selected schools, and technology teachers in these schools. Participation was voluntary and the participants had the right to discontinue participation at any stage of the study without being penalised in any way. Moreover, the participants' right to privacy was respected. Pseudonyms were used to protect the identity of the participants.

Sampling

Six teachers in the Limpopo Province teaching Grade 9 technology were purposively sampled. The participants' qualifications and experience were also considered, since it is believed that teachers with suitable qualifications and experience in teaching technology would be more capable of articulating their understanding of critical thinking and better able to explain how critical thinking skills are enacted in the technology classroom. Technology teachers who had obtained a Bachelor of Education Honours degree with technology as the major subject and had been teaching for at least four years, were considered as experienced teachers for the sake of this study. Ary et al. (2010) clarify that purposefully selected samples are appropriate to provide maximum insight into and understanding of the topic under study.

Data collection

Data was collected from the six participants using semi-structured, face-to-face interviews and classroom observations. Participants were interviewed once and classroom observations were conducted once a week for a period of six weeks in each school. Observations were conducted to confirm what participants highlighted during the interviews. Creswell (2007) highlights the fact that qualitative research typically draws on multiple forms of data, such as interviews and observations, rather than relying on a single data source. Power and Knapp (2011) affirm that, in qualitative research, saturation is a sense of closure that transpires during data collection once new information is no longer forthcoming.

Interviews

The interview questions were derived from Facione's (2015) framework of critical thinking skills. Questions were phrased in such a way that participants responded to each critical thinking skill. The interview questions posed were:

1) What is your definition of critical thinking?
2) How do you support learners to *interpret* the information presented to them?
3) How do you encourage learners to *analyse* statements during discussions?
4) How do you persuade learners to *evaluate* the credibility of the information?
5) How do you support learners to *draw their own conclusions* when solving technology-related problems?
6) How do learners correct their own mistakes while developing technological solutions?

Participants were interviewed once in each school during their free periods in suitable rooms for privacy. On average, these interviews lasted 45 minutes. All participants were asked the same questions to enhance comparability. The interviews were audio recorded and later transcribed. Follow-up questions were asked to allow participants to substantiate their responses, for example, how the participants provided learners with the opportunities to clarify the meanings of any unfamiliar concepts.

Observations

An observation schedule (see Appendix B) based on Facione's (2015) critical thinking skills and critical thinking sub-skills framework was created to guide the observation for each of the stages of the design process. The observations were conducted in the classrooms while the participants were presenting their technology lessons during their normal scheduled periods. Observations were conducted over a period of six weeks, once a week in each of the six schools. During the first term in Grade 9, learners focus on structures. Prior to solving a technology problem, teachers are required to present a scenario describing the context in which the problem posed would meet a need or create an opportunity. According to CAPS (DBE, 2011) learners should design a structure that will solve a problem experienced by a community. However, a detailed scenario is outlined in the CAPS compliant textbook (Marchant, Pretorius, Smith & Smith, 2013, p. 20-21). The scenario: a bridge over a river has collapsed due to flooding and this community struggles to cross the river to access the city. The local authority has placed an advertisement inviting contractors to submit a tender to come up with a solution.

To solve structure-related problems, learners are required to use the mini-PAT template (see Appendix A), which incorporates the design process stages, namely, (a) Investigation skills, which include, *inter alia*, an analysis of existing products in terms of fit-for-purpose, the suitability of the material, safety for users, and the related costs; (b) Design skills, which involve, among others skills, sketching the initial ideas and developing a flow chart, and building a practical solution; (c) Making skills, where learners draft a working drawing and a budget; (d) Evaluation skills, where learners collaboratively evaluate the solution; (e) Communication skills, where learners present the solution in a group (DBE, 2011). The design process is recurring and frequently driven by evaluation (DBE, 2011). All these stages provide an opportunity for teachers to support learners in the development of their critical thinking skills.

Data analysis

The data collected from the interviews were analysed using Facione's (2015) framework, while the data collected by means of observations were analysed using the CAPS design process (DBE, 2011) and Facione's (2015) framework. In the context of this study, the design process can be used to determine the extent to which teachers enact critical thinking skills. The data from the observations were analysed and reported in a narrative manner. The participants' comments that were considered as 'off the topic' were omitted (Burnard, Gill, Treasure, & Chadwick, 2008).

Results and discussion

The results and discussion of the interview will be provided first, followed by the results and a discussion on the observation representing the respective research questions.

Teachers' understanding of the notion of critical thinking

Six participants namely Sipho, Thabo, Tumi, John, Siya, and Kgabo (pseudonyms names) were interviewed. Findings of the interview will be presented as follows: each participant represents a unique setting and will be described separately following the sequence of the six questions, in accordance with Facione's (2015) framework. The interview questions were structured to answer the first research question, namely: What is a technology teacher's understanding of the notion of critical thinking?

Sipho

Sipho defines critical thinking as "a particular way of thinking about a subject and improving one's quality of thinking". This definition resonates with self-regulation, which Facione (2015, p.7) defines as self-consciously monitoring one's cognitive activities, particularly skills in analysis, with a view towards questioning or confirming one's inferential judgements. When asked to explain the way in which he supported learners in the development of their critical thinking skills, Sipho mentioned that he asks learners questions that stimulate them "to think beyond their imagination".

The second question investigated how the participant supports learners in their quest to interpret information. Sipho states that he makes use of diagrams, videos and case studies that involve real life situations. The use of diagrams, videos and case studies empower learners to understand and describe the experiences, situations, beliefs, and events (Facione, 2015). Sipho emphasised the fact that learners independently constructed meaning and, if they could not, the teacher helps them to understand the unfamiliar concepts by providing them with clues. Clarifying meaning is the ability to clarify information and remove confusion (Facione, 2015).

In response to the third question probing how the participant encourages learners to analyse statements during the discussions, Sipho stated that he provides learners with questions to analyse statements. Sipho could not explain the specific kind of questions he uses but Elder and Paul (2010) assert that asking analytical questions is a very important approach used to stimulate thinking. Furthermore, effective thinking depends on the ability to identify the components of thinking by asking questions that are directed towards those components. The next question prompted the participant to explain how he supports learners to draw their own conclusions when solving technological problems. Sipho mentioned that he encourages learners to look at different sources of information and to decide which source is relevant to the context. Some of the features of critical thinking (Inference) involve the ability to identify and secure the appropriate element that is required to draw reasonable conclusions (Facione, 2015). The final question intended to determine whether learners are able to correct their own mistakes. In accordance with CAPS (DBE, 2011), learners are required to produce an evaluation tool in order to evaluate their solution and the solutions of other groups. Sipho stated that the technical solutions for the mini-PAT project should function, and if they do not then the learners within a group must do fault finding.

Thabo

Thabo defines critical thinking as "a skill that revolves around an interpretation of issues in order to make judgement". This statement refers to evaluation and interpretation, i.e. understanding and articulating the meaning or importance of a broad range of, among others, experiences, situations, data, events, and judgement (Facione, 2015). Expanding on the way in which he supported learners' efforts to develop critical thinking skills, Thabo mentioned that learners are presented with a scenario and they are expected to interpret and identify the problem within the scenario. CAPS (DBE, 2011) emphasises that teachers should present a scenario by describing the context in which a particular technology problem could be used to meet a need or create an opportunity.

The third question was posed to determine how the participant encourages learners to analyse statements during the discussions. Analysing arguments means the ability to identify and determine whether the claim expressed, *inter alia*, supports the intended conclusion (Facione, 2015). Thabo said that he asks the learners questions that challenge them to examine the information. The participant was further asked to substantiate how he supported learners in their quest to analyse an argument. Thabo emphasised that, depending on the nature of the problem, learners are encouraged to select the best idea and build a solid argument which is important to solve the problem.

The next question prompted the participant to explain how he helped learners to draw their own conclusions when solving technological problems. Thabo mentioned that, once a problem has been identified, learners suggest various possible solutions and consider the most suitable one. CAPS (DBE, 2011) stipulates that learners are required to select a solution that appropriately satisfies the specifications given. The final question investigated whether learners are able to correct their own mistakes. Thabo stated that learners collectively verify whether they have followed the plan and use a checklist to assess this.

Tumi

Tumi said that "critical thinking entails various intellectual skills including analysis, assessing, and reconstruction of information". This description refers to interpretation and mainly analysis as it encompasses examining ideas, detecting arguments, and analysing arguments (Facione, 2015). When asked how he supported learners in their quest to develop critical thinking skills, Tumi indicated that the nature of the tests, assignments and projects *per se* stimulate learners to develop critical thinking skills. Tumi is under the impression that the activities, which are outlines in the prescribed textbook, ordinarily stimulate critical thinking. For instance, learners might be asked to discuss why diamonds are used in the industry to cut tools or why a dehumidifying system would be used in the construction of bridges that are built inland and not in the construction of bridges built at the coast (Marchant et al., 2013). The final question investigated whether learners are able to correct their own mistakes. Tumi said that each group submits its project and all learners assess whether it works which refers to the practice of self-regulation including self-examination and self-correction (Facione, 2015).

John

John defines critical thinking as "the ability to criticize, to compare and contrast. In addition, it means going into deeper analysis". The analysis being referred to by John focuses on examining ideas involving, as Facione (2015) states, comparing or contrasting ideas, concepts or statements. Elaborating on the way he encourages learners to analyse statements during the discussions, John indicated that learners "should not accept any information presented to them" but that "they should be critical". The participant was further probed to explain how he supported learners in their quest to analyse an argument. John emphasised that being able to analyse facts within an argument enables learners to examine ideas and identify the arguments. The fifth question posed prompted the participant to explain how he helps learners to draw their own conclusions when solving technological problems. John mentioned that learners exchange ideas until they reach a conclusion. The final question probed whether learners are able to correct their own mistakes. John stated that learners first evaluate their own projects before submitting them. Furthermore, once submitted, all learners collectively evaluate all the projects.

Siya

Siya defines critical thinking as “the ability to think clearly about what to do or believe”. Siya stated that he supported learners to develop critical thinking skills “by assisting learners to identify a problem in a scenario that the teacher presented”. Providing the scenario in technology empowers learners to understand the context of the problem to be solved (DBE, 2011) but the scenario also stimulates learners to apply their minds. In response to the second question, Siya mentioned that he supports learners to interpret information “by giving learners pictures with multiple views for learners to compare or match different views”.

The fifth question prompted the participant to explain how he supports learners to draw their own conclusions when solving technological problems. Siya indicated that learners compare possible solutions and consider which solution is the most suitable one. He noted that the prescribed design process helps learners to develop alternative solutions and select the most appropriate one. The final question was intended to find out whether learners are able to correct their own mistakes. Siya said that learners evaluate their solution and determine whether their solutions are operational.

Kgabo

Khabo defines critical thinking as “a state of right or accurate thinking, which involves judging and deciding on interpretation and analysis”. Interpretation and analysis are primary features of critical thinking (Facione, 2015). Kgabo has demonstrated a sound understanding of what critical thinking entails. Kgabo said that he supports his learners in developing critical thinking skills by allowing learners to work collaboratively in order for them to participate effectively in a range of conversations with diverse teammates, building on each other’s ideas and expressing their own ideas clearly.

The third question was intended to determine how the participant encourages learners to analyse statements during the discussions. Kgabo indicated that he did this by encouraging learners to reflect on, and question, what they have learnt. The participant was further probed on how he supports learners to examine ideas during the learning experience. Kgabo mentioned that he encourages learners to assess their ideas. A follow-up question was asked to allow the participant to explain how he supported learners to analyse an argument. Kgabo emphasised that the scenario that he describes, before learners begin to solve a problem, provides the basis for learners to analyse the arguments. The final question was intended to find out whether learners are able to correct their own mistakes. Kgabo indicated that learners evaluate their solutions and make the necessary and appropriate improvements.

Teachers’ actualisation of critical thinking in their classrooms

Classroom observations were conducted for six weeks to determine the way in which technology teachers enact critical thinking skills in learners. According to CAPS (DBE, 2011), Grade 9 learners focus on structures in the first term. Technology is allocated two hours per week, of which one hour should be reserved for practical work (DBE, 2011). However, the participants stressed that they teach theory for the first three weeks each term and reserved the remaining three weeks for practical work. In this way, learners have a better understanding of the theory before application. The observation schedule (see

Appendix B) was used to determine the extent to which the participants promoted critical thinking skills.

In the first three weeks, all participants (Sipho, Thabo, Tumi, John, Siya, and Kgabo) taught learners about static and dynamic forces, even and uneven loads, the strength of the materials, and properties of the materials. The participants literally used the prescribed textbook, without attempts to stimulate learners to develop critical thinking skills. Teaching was dominated by theory. However, there were sporadic occasions were learners were presented with the opportunity to reason. For instance, in Tumi's and Siya's class, learners were presented with pictures to identify different forces and in this activity, learners were asked to state the reasons for the effect of an uneven load on the see-saw. This was an instance were learners analysed arguments.

During the fourth week, all participants revised the mini-PAT and outlined the problem which a community was faced with. A bridge which the community used to cross had collapsed. Two participants, Thabo and Kgabo, instructed learners to collectively develop the solution at home, citing lack of resources at school. Sipho, Tumi, John, and Siya presented learners with the mini-PAT template (see Appendix A) and instructed them to address each aspect of the mini-PAT. Learners were required to (a) Identify the problem and analyse the existing products, (b) Sketch the design brief and a flow chart, (c) Construct a working drawing and provide a budget, (d) Make a viable solution, and (e) Evaluate the solution and present the solution in a group.

When identifying the problem, learners in all the six schools concluded that the bridge was the suitable solution to the problem. This conclusion was intensively discussed among the learners in groups until they reached consensus. Drawing conclusions based on consensus signifies inference, which is one of the critical thinking skills that Facione alluded to (see Table 1). In relation to the design brief, learners sketched alternative solutions without the appropriate dimensions (2D/3D). The design process requires cognizance, knowledge, and skills associated with graphics (DBE, 2011). Learners did not provide the flow chart as required by the mini-PAT. In terms of constructing a working drawing and budget, learners drafted an unrealistic budget. The bridges, which were supposed to be viable solutions, were built using card boxes. The use of cardboard boxes was a constraint that should have been highlighted during the design brief. With regard to evaluating the solution, none of the participants had or developed the criteria required to evaluate the solution.

Conclusion

The participants demonstrated that they are able to support learners to interpret information, to some extent analyse information, support learners to draw conclusions (inference), and correct their own mistakes (self-regulation). The mini-PAT and the design process implicitly empower teachers to support learners to develop critical thinking skills. In order to enact critical thinking skills effectively, teachers should examine various critical thinking models and understand the dynamics of cognitive mechanisms. Future studies should focus on the way in which technology teachers support learners to evaluate information and establish the credibility of information. There is a huge discrepancy between what technology teachers say and what they do in reality: teachers' explication of critical thinking is different from the way they enact critical thinking skills in the classroom.

References

Ary, D., Jacobs, L.C. & Sorensen, C. (2010). *Introduction to Research in Education*. Belmont: Wadsworth Cengage Learning.

Burnard, E., Gill, P., Treasure, E., & Chadwick, B. (2008). Analysing and presenting qualitative data, *British Dental Journal*, 204(8), 429-432.

Creswell, J.W. (2007). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches.* Thousand Oaks: Sage Publications, Inc.

Department of Basic Education. (2011). *Curriculum and Assessment Policy Statement (CAPS) of Technology Grades 7-9*. Pretoria: Department of Education.

Dewey, J. (1910). *How we think*. Boston: D.C. Heath.

Duran, M., & Sendaĝ, S. (2012). A preliminary investigation into critical thinking skills of urban high school students: role of an IT/STEM program. *Creative Education*, 3(2), 241-250.

Dwyer, C., Hogan, M., & Stewart, I. (2014). An integrated critical thinking framework for the 21st century. *Thinking Skills and Creativity,* 12, 43-52.

Elder, L., & Paul, R. (2010). *The art of asking essential questions: based on critical thinking concepts and Socratic principles*. Fifth edition. Dillon Beach, CA: Foundation for Critical Thinking.

Facione, P.A. (1990). *Critical Thinking: a statement of expert consensus for purpose of educational assessment and instruction*. Newark, Del: American Philosophical Association.

Facione, P.A. (2015). *Critical Thinking: what it is and why it counts.* Millbrae, CA: The California Academic Press.

Goldschmidt, G. & Rodgers, P.A. (2013). The design thinking approaches of three different groups of designers based on self-reports. *Design Studies*, 34(4), 454-471.

Grosser, M. & Nel, M. (2013). The relationship between the critical thinking skills and the academic language proficiency of prospective teachers. *South African Journal of Education*, 33(2), 1-17.

Haas, P.F. & Keeley, S.M. (1998). Coping with faculty resistance to teach critical thinking. *College Teaching*, 46(2), 63-67.

Halpern, D.F. (2014). *Thought and knowledge: an introduction to critical thinking*. 5th ed. New York: Psychology Press.

Hitchcock, D. (2018). *Critical thinking*. Stanford Encyclopaedia of Philosophy. Stanford, CA: Centre for the Study of Language and Information.

Jonassen, D.H. (2011). *Design problems for secondary students*. University of Missouri: National Science Foundation.

Ku, K.Y.L. (2009). Assessing learners' critical thinking performance: arguing for measurements using multi-response format. *Thinking Skills and Creativity*, 4, 70-76.

Lombard, K. & Grosser, M. (2008). Critical thinking: are the ideals of OBE failing us or are we failing the ideals of OBE? *South African Journal of Education*, 28, 561-579.

Makina, A. (2010). The role of visualisation in developing critical thinking in mathematics. *Perspectives in Education,* 28(1), 24-32.

Marchant, J., Pretorius, A., Smith, K. & Smith, S. (2013). *Spot on Technology Grade 9: Learners' Book*. Sandton: Heinemann.

Mathumbu, D., Rauscher, W. & Braun, M. (2014). Knowledge and cognitive process dimensions of Technology teachers' lesson objectives. *South African Journal of Education*, 34(3), 1-8.

McPeck, J.E. (2017). *Critical thinking and education*. New York: Routledge.

Mioduser, D. & Dagan, O. (2007). The effect of alternative approaches to design instruction (structural or functional) on students' mental models of technological design processes. *International Journal of Technology and Design Education,* 17, 135-148.
Mulnix, J.W. (2012). Thinking critically about critical thinking. *Educational Philosophy and Theory*, 44(5), 464-478.
Pitchers, R.T., & Soden, R. (2000). Critical thinking in education: a review. *Educational Research*, 42, 237-249.
Potter, P. (2013). Technologists talk: making the links between design, problem solving and experiences with hard materials. *International Journal of Technology and Design Education*, 23, 69-85.
Powers, B.A. & Knapp, T.R. (2011). *Dictionary of Nursing Theory and Research*. New York: Springer Publishing Company.
Reed, J.H. & Kromrey, J.D. (2001). Teaching critical thinking in a community college history course: empirical evidence from infusing Paul's model. *College Student Journal*, 35(2), 201-216.
Siegel, H. (2010). Critical thinking. *International Encyclopaedia of Education*, 6, 141-145.
Visser, W. (2009). Design: one, but in different forms. *Design Studies*, 30, 187-223.
Yang, T.Y. & Chou, H.A. (2008). Beyond critical thinking skills: investigating the relationship between critical thinking skills and dispositions through different online instructional strategies. *British Journal of Education Technology*, 39(4), 606-684.

Appendix A

Mini-Practical Assessment Task

Investigate (conduct meaningful and relevant research)

The design brief with specifications and constraints

Sketches of two possible ideas per learner

A flowchart showing the process

Working drawings of the final solution decided upon

A budget

A model of the final solution an evaluation instrument

A presentation (oral, written, graphic or electronic)

Appendix B
Observation Schedule

Critical Thinking Skills / Design process (Mini-PAT)	**Interpretation**	Categorize	Translate significance	Clarify meaning	**Analysis**	Examine ideas	Identify argument	Analyse arguments	**Evaluate**	Assess credibility of claim	Assess quality of arguments	**Inference**	Query evidence	Conjure alternatives	Draw conclusions using inductive reasoning	**Explanation**	State results	Justify the procedure	Present argument	**Self-regulation**	Self-examination	Self-correction
Investigation																						
Provide scenario																						
Analyse existing products																						
Realistic costs																						
Design																						
Design brief																						
Flow chart																						
Decide final solution																						
Make																						
Working drawing																						
Budget																						
Model of viable solution																						
Evaluate																						
Evaluation instrument																						
Communication																						
Team presentation																						
Compile a report																						