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Assessing the Implementation of Critical Thinking Skills in the University: A Focus on Technology Education

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ABSTRACT
There is a great demand for universities to foster critical thinking skills and this requires universities to develop effective assessment methods. Critical thinking skills enable students to interpret and integrate new information and the manner in which it is applied in unfamiliar settings. The purpose of this article is to determine the extent to which technology lecturers set summative questions that stimulate students to apply critical thinking skills. Facione's framework for critical thinking skills was used to assess how technology lecturers stimulate critical thinking during the summative assessment. A qualitative approach was applied using a case study design. The sample constituted four technology lecturers who taught four technology modules at the undergraduate level. The findings indicated that technology lecturers in the selected university, to some extent, elicited critical thinking skills, which is important as modern education requires students to develop critical thinking skills to find technological solutions to everyday problems.

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INTRODUCTION
For quite some time, the importance of critical thinking has been proclaimed as being one of the most desirable outcomes of higher education.[1] This enables students to reason and make decisions that are based on sound judgement. Modern education requires universities to teach critical thinking skills in order to support students' ability to reason competently, particularly in a rapidly changing world.[2] Students should not rely on textbook knowledge, but should rather develop skills such as evaluating knowledge and arguing using sound reasoning skills, as these are necessary skills in the workplace and social settings.[3] Howe describes critical thinking as a process in which an individual is actively engaged in analysis, reasoning, questioning, and creatively searching for alternatives in an effort to solve a problem or to make a decision or judgement.[4]

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[1] Gerry Dunne, "Beyond Critical Thinking to Critical Being: Criticality in Higher Education and Life," *International Journal of Educational Research* 71 (2015): 86–99; Jan Sermeus, M. De Cock, and J. Elen, "Critical Thinking in Electricity and Magnetism: Assessing and Stimulating Secondary School Students," *International Journal of Science Education* 43, no. 16 (November 2, 2021): 2597–2617, https://doi.org/10.1080/09500693.2021.1979682.
[2] Kelly Y L Ku, "Assessing Students' Critical Thinking Performance: Urging for Measurements Using Multi-Response Format," *Thinking Skills and Creativity* 4, no. 1 (2009): 70–76.
[3] Ku, "Assessing Students' Critical Thinking Performance: Urging for Measurements Using Multi-Response Format."
[4] Edward R Howe, "Canadian and Japanese Teachers' Conceptions of Critical Thinking: A Comparative Study," *Teachers and Teaching* 10, no. 5 (2004): 505–25.

Critical thinking is the art of analysing and evaluating thinking to improve it.[5] In short, critical thinking is self-directed, self-disciplined, self-monitored, and self-corrective thinking. Renaud and Murray highlight common critical thinking as (i) identifying central issues and assumptions; (ii) making correct inferences from data; (iii) deducting conclusions from the data provided; (iv) interpreting whether conclusions are warranted; (v) and evaluating evidence or authority.[6]

According to Halpern, the fundamental reason why university programmes should foster critical thinking is that students should acquire thinking skills such as synthesis and analysis, and be able to substantiate the conclusions that are reached.[7] It is essential to develop appropriate assessment methods that are realistic in recognising students' cognitive skills and their disposition towards critical thinking. Appropriate assessment is therefore required to determine the extent to which students develop critical thinking skills. An appropriate assessment should be based on a similar context to real life experiences students encounter. Facione finds that in a lifetime, critical thinking skills are required by everyone, particularly when solving problems and making decisions that influence humanity.[8] In addition, the acquisition of knowledge requires the capacity to think critically because learning necessitates students to interpret and integrate new knowledge and its realistic application when facing unfamiliar circumstances. Facione (2013) argues that it is essential to develop valid and reliable assessment methods through which lecturers can make realistic conclusions about students' critical thinking skills.[9] Furthermore, these critical thinking assessment methods should not merely reward students for arriving at the correct answer but should acknowledge how the students have applied critical thinking to reach a suitable answer. According to Ennis, various critical thinking assessment methods are not all-inclusive, particularly those that are easily applied, such as multiple-choice tests.[10] Multiple-choice tests generally fail to provide opportunities for students to apply critical thinking skills.

Howe acknowledges that several university programmes are developed to foster critical thinking, however, the lecturers thereof concede that critical thinking has not been methodically implemented.[11] Ku affirms that the challenges in implementing critical thinking are manifold.[12] One of the challenges is a lack of appropriate assessment to measure the strengths and weaknesses of the students' critical thinking skills. It may be difficult to examine the efficiency of any university programme that is intended to foster critical thinking skills without the appropriate assessment methods that develop students' critical thinking skills. Norris asserts that it is difficult to recognise the objective criteria used to assess critical thinking.[13] Students' characters involve willpower, which is complex to measure.

The research by Mtshali in one of the South African universities revealed that technological practical assessment does not encourage critical thinking skills.[14] Hart, et al. conducted a study that explored the higher education students' critical thinking skills in one of the Australian universities

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[5] R Paul and L Elder, "The Miniature Guide to Critical Thinking Tools and Concepts" (Foundation for Critical Thinking Press: Tomales, CA, 2007); Richard Paul and Gerald M. Nosich, "A Model for the National Assessment of Higher Order Thinking." (Foundation for Critical Thinking, 4655 Sonoma Mountain Road, Santa Rosa, CA 95404 ($3)., 1992).
[6] Robert D Renaud and Harry G Murray, "A Comparison of a Subject-Specific and a General Measure of Critical Thinking," *Thinking Skills and Creativity* 3, no. 2 (2008): 85–93.
[7] Diane F Halpern, "Assessing the Effectiveness of Critical Thinking Instruction," *The Journal of General Education* 50, no. 4 (2001): 270–86.
[8] Peter Facione, *Critical Thinking: What It Is and Why It Counts* (Insight Assessment, Pearson Education, 2015), https://www.insightassessment.com/article/critical-thinking-what-it-is-and-why-it-counts.
[9] Peter Facione, "The California Critical Thinking Skills Test: College Level Experimental Validation and Content Validity," January 1, 1990.
[10] Robert H. Ennis, "Critical Thinking Assessment," *Theory Into Practice* 32, no. 3 (June 1993): 179–86, https://doi.org/10.1080/00405849309543594.
[11] Howe, "Canadian and Japanese Teachers' Conceptions of Critical Thinking: A Comparative Study."
[12] Ku, "Assessing Students' Critical Thinking Performance: Urging for Measurements Using Multi-Response Format."
[13] Stephen P Norris, "Can We Test Validly for Critical Thinking?," *Educational Researcher* 18, no. 9 (1989): 21–26.
[14] Thokozani I Mtshali, "Critical Thinking Skills for Civil Technology Practical Assessment Tasks (PATs)," *World Transactions on Engineering and Technology Education, WIETE* 18, no. 2 (2020): 237–41.

using a critical thinking assessment tool.[15] The assessment tool consisted of both selected and constructed-response items that were designed to reflect the five critical thinking dimensions proposed. The study revealed that there was no relationship between performance on the critical thinking assessment tool and general disposition towards complex thinking. It was also found that participants generally performed poorly on the assessment tool. Participants performed most poorly with respect to developing sound and valid arguments.

There are limited studies that were conducted on critical thinking assessment, particularly in South Africa. The research investigated by Van Rensburg and Rauscher focused on the strategies for fostering critical thinking dispositions in the technology classroom with reference to Grade 8 and 9 teachers.[16] Mtshali conducted a study that used a practical assessment task to gauge the extent to which critical thinking skills could be fostered.[17] However, the practical assessment task is a concept that is predominantly used in high schools, not universities.

The purpose of this article is to determine the extent to which technology lecturers assess critical thinking skills. There is little empirical evidence regarding how to assess critical thinking, particularly in South African universities. Ku argues that there is a great demand globally for universities to develop learning activities that foster critical thinking skills.[18] To determine whether universities are successful in responding to these demands, the appropriate assessment of critical thinking is very important. The research question this study aimed to answer is as follows: To what extent do technology lecturers assess critical thinking during the summative assessment?

LITERATURE REVIEW

The word critical often has a negative connotation. Critical individuals seem to be determined to fault-finding and ungenerous in judgement. However, the etymology of the word can be traced from the Latin 'criticus' (able to discern or judge) directly to the Greek word 'krísimos' which means criterion or standard for judging. Therefore, to think critically means to think with balanced discerning judgement.[19] The concept of assessment originates from the Latin verb 'assidere', which means to sit with.[20] Basically, assessment indicates the measuring of something by gathering information that will be used for a particular intention. According to Ennis, the purpose of assessment in critical thinking is inter alia, to determine the extent of students' critical thinking; to provide feedback about their critical thinking abilities and to encourage them to improve their critical thinking skills.[21] Ku asserts that the assessment of critical thinking should be in harmony with understanding critical thinking.[22] Assessment is conceivably the essential process for effective teaching.[23] According to Facione, the most suitable assessment strategy would be a broad, non-obstructive observation by a proficient teacher who can recognise critical thinking skills while the students or learners interact in various natural contexts.[24] Teaching, learning and assessment strategies should be consistent with the nature

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[15] Claire Hart et al., "Exploring Higher Education Students' Critical Thinking Skills through Content Analysis," *Thinking Skills and Creativity* 41 (2021): 100877.

[16] Joalise Janse van Rensburg and Willem Rauscher, "Strategies for Fostering Critical Thinking Dispositions in the Technology Classroom," *International Journal of Technology and Design Education* 32, no. 4 (September 5, 2022): 2151–71, https://doi.org/10.1007/s10798-021-09690-6.

[17] Mtshali, "Critical Thinking Skills for Civil Technology Practical Assessment Tasks (PATs)."

[18] Ku, "Assessing Students' Critical Thinking Performance: Urging for Measurements Using Multi-Response Format."

[19] Erick Wilberding, *Socratic Methods in the Classroom: Encouraging Critical Thinking and Problem Solving Through Dialogue (Grades 8-12)* (Routledge, 2021).

[20] L W Meyer and P G Warnich, "Outcomes-Based Education and Outcomes-Based Assessment in South African Schools: The Way Forward," *Meyer, L, Lombard, K, Warnich, P & Wolhuter, C. Outcomes-Based Assessment for South African Teachers, Van Schaik's Publishers: Pretoria*, 2010, 161–73.

[21] Ennis, "Critical Thinking Assessment."

[22] Ku, "Assessing Students' Critical Thinking Performance: Urging for Measurements Using Multi-Response Format."

[23] Dylan Wiliam, "Assessment: The Bridge between Teaching and Learning," *Voices from the Middle* 21, no. 2 (2013): 15.

[24] Facione, *Critical Thinking: What It Is and Why It Counts* .

of technology, the extent of students' technological practice, and specific conceptual and procedural knowledge.[25]

Technology is fundamentally a cognitive process that involves a social and physical context, with the thinking being related to the composition of the artefacts and the tools of the trade. The primary aspect of technology literacy is the perception that intellectual and practical resources are used to mediate in society through the advancement of products, systems and environments. This results from extensive techniques, relevant resources and learning in design and technology, which involves generating alternative ideas to solve technological problems.[26] Airasian and Miranda find that it is broadly perceived that information acquired during an assessment is somewhat influenced by what occurred during teaching, especially when both the teaching and assessment are orientated towards predetermined objectives.[27]

There are several critical instruments, namely, the Ennis-Weir Critical Thinking Essay Test (EWCTET);[28] the Cornell Critical Thinking Test;[29] the California Critical Thinking Skills Test (CCTST);[30] and the Halpern Critical Thinking Assessment (HCTA).[31] EWCTET is a general test of critical thinking that lays emphasis on the context of the argument. Students are instructed to read and think about the letter and subsequently write the nine paragraphs evaluating the argument of the letter. CCTT focuses on induction, credibility, observation, deduction, and assumption identification. CCTST utilizes overall scores on interpretation, arguments analysis, evaluation, inference, deductive reasoning and inductive reasoning. Separate percentile norms are used for students irrespective of whether they have completed a university-level critical thinking programme or not. HCTA outlines a list of thinking skills that students could be assessed. Amongst others, the list provides support for a conclusion, using analogies, evaluating evidence, and combinatory reasoning.

This study used Facione's framework (Table 1) of critical thinking skills as it was deemed to be more comprehensive in the context of the topic.

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[25] Alister Jones and Judy Moreland, "Enhancing Practicing Primary School Teachers' Pedagogical Content Knowledge in Technology," *International Journal of Technology and Design Education* 14, no. 2 (May 2004): 121–40, https://doi.org/10.1023/B:ITDE.0000026513.48316.39.
[26] Paul Black, "Formative Assessment in the Learning and Teaching of Design and Technology," *Design and Technology Education: An International Journal* 13, no. 3 (2008).
[27] Peter W Airasian and Helena Miranda, "The Role of Assessment in the Revised Taxonomy," *Theory into Practice* 41, no. 4 (2002): 249–54.
[28] Robert Hugh Ennis and Eric Edward Weir, *The Ennis-Weir Critical Thinking Essay Test: An Instrument for Teaching and Testing* (Midwest Publications, 1985).
[29] Insight Assessment, "California Critical Thinking Test (CCTST)," 2021, https://www.insightassessment.com/.
[30] Facione, "The California Critical Thinking Skills Test: College Level Experimental Validation and Content Validity."
[31] Diane F Halpern, *The Nature and Nurture of Critical Thinking.* (Cambridge University Press, 2007).

Table 1: Critical Thinking Skills (Facione, 2020)

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

The sub-skills in the table serve as the basic aspects of the main skills. Interpretation refers to the aptitude to classify information, translate the implication and provide clarity of the meanings. Analysis denotes the competence to scrutinise the thoughts, to examine and analyse the arguments. Evaluation signifies the ability to assess assertions and points of view. Inference refers to the aptitude to enquiry evidence, envisage alternatives and draw a conclusion. Explanation denotes the ability to present the results and substantiate the process. Self-regulation signifies self-reflection.

METHODOLOGY

A qualitative research approach was employed to assess and understand how technology lecturers in the university implement critical thinking. Ary, et al. emphasise that researchers who apply qualitative approaches pursue the understanding of a phenomenon by concentrating on the whole picture instead of breaking it down into variables.[32] A case study has been applied to obtain an exhaustive description and understanding of the entity.[33] The sample constituted four technology lecturers who taught four technology modules at the undergraduate level at Bakone University in South Africa. Pseudonyms were used to protect the identity of the university. Participation was conducted voluntarily and the participants were free to withdraw at any stage of data collection without being humiliated in any manner. Most importantly, the participants' right to privacy was respected and pseudonyms were used to protect their identity. Four technology examination papers (levels one to four) and the programme that outlined the scope of teaching technology in the university were collected as data. These modules focused on four technology strands namely, structures, processing, mechanical systems and control, and electrical systems and control.

After completing the programme, prospective technology teachers are expected to support learners to identify and solve problems and make decisions using critical and creative thinking.[34] Thus,

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[32] Donald Ary, Lucy Cheser Jacobs, and Chris Sorensen, *Introduction to Research in Education* (Belmont: Wadsworth Cengage Learning, 2012).

[33] Louis Cohen, Lawrence Manion, and Keith Morrison, *Research Methods in Education* (Eighth edition. | New York: Routledge, 2018.: Routledge, 2007), https://doi.org/10.4324/9781315456539; Sharan B Merriam, *Qualitative Research and Case Study Applications in Education. Revised and Expanded from" Case Study Research in Education.".* (ERIC, 1998).

[34] Department of Basic Education., *Curriculum and Assessment Policy Statement Grades R-12, First Additional Language* (Pretoria: Department of Basic Education, 2011).

document analysis was the data collection method chosen in this article. Maree highlights that documents are often used as a data collection method to help clarify the problem under investigation.[35] Documents are considered sources of information in social research and could be used in qualitative research.[36] It is rather rare for studies to be conducted without some form of documentary method. Examination papers were used as documents in this study. Examination papers are frequently used for summative assessment to determine the success of learning at the end of acquiring the learning experience. Furthermore, examination papers supplement formative assessment to determine whether the students satisfied the predetermined performance descriptions to proceed to the next level of study.

Data collection

The data was collected from the four participants using semi-structured, face-to-face interviews and document analysis. Previous question papers that serve as document analyses were examined to verify information collected through interviews. A combination of data sources such as interviews and relevant documents improves the prospect that the phenomenon being studied is understood from different perspectives.[37] To effectively use semi-structured interviews, questions were prepared in advance and this allowed the researcher to appear knowledgeable during the interviews. Participants were interviewed once within a day since they are located in the same university. On average, these interviews lasted for thirty (30) minutes. Moreover, the participants were allowed to express themselves freely without interruption. Brinkmann and Kvale affirm that semi-structured interviews enable the researchers to comprehend the real-life experience of the subject from the participant's own standpoint.[38] Four participants, Moses, John, Peter and Paul (pseudonyms), were interviewed. The following questions were phrased in such a way to allow the participants to share their experiences:

(a) To what extent does the technology education programme promote critical thinking skills?
(b) How do teachers support students to develop critical thinking skills in their respective modules?
(c) What are the benefits of critical thinking outside the classroom context?
(d) Which instrument or model do teachers apply to measure critical thinking skills when setting examination questions?

The same question weres asked all of the participants to enhance the credibility of the study.[39] Moreover, the questions asked enabled the researcher to determine whether the data collected from the interviews corroborated with the data collected from document analysis.

Data analysis

Facione's framework was used to analyse the data. The questions that were asked by the technology lecturers during the summative assessment were examined as to whether they prompted students to apply critical thinking skills or not. However, the participants' responses about how they promoted critical thinking skills were analysed under thematic data analysis.[40] Emerging themes were identified and analysed. Moreover, the data was presented narratively.

FINDINGS AND DISCUSSION

The themes that emerged from the data are discussed first and followed by document analysis. Data analysis is presented narratively. Four themes emerged from the four semi-structured questions namely, Problem-based learning, Procedural knowledge, Divergent thinking and Problem-solving.

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[35] Kobus Maree, *First Steps in Research* (Hatfield: Van Schaik Publishers, 2014).
[36] S Sarantakos, "Social Research" (London: Macmillan International Higher Education, 2012).
[37] Ary, Jacobs, and Sorensen, *Introduction to Research in Education*.
[38] Svend Brinkmann and Steinar Kvale, *Doing Interviews*, vol. 2 (Sage, 2018).
[39] Ary, Jacobs, and Sorensen, *Introduction to Research in Education*.
[40] Ary, Jacobs, and Sorensen, *Introduction to Research in Education*.

Problem-based learning

Problem-based learning (PBL) applies constructivist principles to cultivate the application of prior knowledge, collaborative learning, and active engagement. To initiate a PBL activity, a small group of students analyses a problem, identifies relevant facts and applies existing knowledge and experiences to solve a problem.[41] Problem-based learning is a student-centred instruction in which students learn about a subject through the experience of solving an open-ended problem found in the literature. The PBL process does not focus on problem-solving with a defined solution, but it allows for the advancement of other required skills and characteristics such as knowledge acquirement, improved group collaboration and communication.[42] When the participants were asked about the extent to which technology programme promotes critical thinking skills, they responded as follows:

Moses: The programme provides a chance for students to critique Practical Assessment Tasks that are outlined by the Department of Basic Education.

John: The programme gives students the opportunity to learn by identifying and solving problems.

Peter: The programme supports students to effortlessly assimilate new technical concepts.

Paul: To a little extent and it depends on the lecturer's expertise.

Procedural Knowledge

Procedural knowledge could be traced from Wilberding who avows that the manifestation of technological knowledge is based on procedural and conceptual knowledge.[43] Procedural knowledge comprises such things as design, problem-solving, planning, systems analysis (or systems approach), optimisation, modelling, and strategic thinking (heuristics, algorithms and metacognition). Procedural knowledge refers to how to do or make something and declarative knowledge refers to facts, concepts and the relationships among concepts or to an integrated conceptual understanding. Procedural knowledge denotes knowledge about action or knowledge communicated through processes of making things.[44] Activity in technology education includes processes such as inventing, designing, crafting, maintaining, manufacturing, working and operating.[45] When the participants were asked whether teachers support students to develop critical thinking skills in their respective modules, they responded as follows:

Moses: Provide the students with activities that are aligned with the problem solving taxonomy.

John: Students are presented with structured, deliberate, and repetitive exposure including practical activities.

Peter: Emphasis on pedagogical aspects that help to reinforce theoretical concepts.

Paul: Expose students to exploratory concepts to allow them to individually investigate or conduct research.

Divergent Thinking

Divergent thinking was conceptualised by William with a range of factors, creative ideation most often focuses on three dimensions, fluency, flexibility and originality, each scored to approximate different components of divergent thinking capacity.[46] Fluency signifies the number of diverse ideas or solutions

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[41] Mtshali, "Critical Thinking Skills for Civil Technology Practical Assessment Tasks (PATs)."

[42] Wilberding, *Socratic Methods in the Classroom: Encouraging Critical Thinking and Problem Solving Through Dialogue (Grades 8-12).*

[43] Wilberding, *Socratic Methods in the Classroom: Encouraging Critical Thinking and Problem Solving Through Dialogue (Grades 8-12).*

[44] Ku, "Assessing Students' Critical Thinking Performance: Urging for Measurements Using Multi-Response Format."

[45] Sermeus, De Cock, and Elen, "Critical Thinking in Electricity and Magnetism: Assessing and Stimulating Secondary School Students."

[46] Dylan Wiliam, "What Is Assessment for Learning?," *Studies in Educational Evaluation* 37, no. 1 (March 2011): 3–14, https://doi.org/10.1016/j.stueduc.2011.03.001.

created by an individual in response to the prompt. Flexibility represents the associative or categorical difference between ideas created, regularly determined as the number of distinctive sorts that ideas made fit into. Originality symbolises the newness and uniqueness of an idea, most often evaluated as being theoretically divergent from all other ideas produced by a sample.[47] Divergent thinking is defined as a thought process or thinking technique applied towards exploring numerous solutions and is of particular significance for creativity as it empowers students to think in multiple ways.[48] When the participants were asked about the benefits of critical thinking outside the classroom context, they responded as follows:

Moses: Students are expected to think quickly and effortlessly when solving problems encountered.

John: Students could eventually become independent, accountable, develop entrepreneurship skills and make good decisions.

Peter: Develop problem-solving skills.

Paul: Develop the ability to analyse information and integrate diverse sources of knowledge in solving problems.

Problem-solving

Problem-solving in technology education or technology design was first presented by McCade[49] and followed by Jonassen[50] and Hill.[51] McCade declares that technological problem-solving can be divided into three categories: design, troubleshooting and technology assessment (impact evaluation).[52] Hill asserts that a key element in the study of technology and the development of technological literacy is the task of solving problems.[53] Jonassen describes the variety of problem-solving learning outcomes by differentiating between well-structured and ill-structured problems with regard to their instructional design requirements.[54] Instructional designs for well-structured problems are entrenched in information-processing theory, but instructional designs for ill-structured problems essentially share expectations with constructivism and situated cognition. Problem-solving starts with problem identification, definition, solution generation, outcome anticipation, solution implementation and reflection.[55] However, in technology education, the design process is the prominent model used to solve technological problems. Mtshali affirms that problem-solving and design are prominent among sorts of procedural knowledge pertinent to technology and the situated learning perspective necessitates technology teachers to be conversant with the student experience of these processes.[56] When the participants were asked about the nature of the instrument or model applied to measure critical thinking skills when setting examination questions, they responded as follows:

Moses: Problem-solving taxonomy.

John: Practical projects.

Peter: Practical-based scenario.

Paul: Problem-based scenario.

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[47] Sermeus, De Cock, and Elen, "Critical Thinking in Electricity and Magnetism: Assessing and Stimulating Secondary School Students."

[48] Mtshali, "Critical Thinking Skills for Civil Technology Practical Assessment Tasks (PATs)."

[49] Joseph McCade, "Problem Solving: Much More than Just Design," *Journal of Technology* 2, no. 1 (1990).

[50] David H Jonassen, "Instructional Design Models for Well-Structured and III-Structured Problem-Solving Learning Outcomes," *Educational Technology Research and Development* 45, no. 1 (1997): 65–94.

[51] Roger B. Hill, "The Design of An Instrument to Assess Problem Solving Activities in Technology Education," *Journal of Technology Education* 9, no. 1 (September 1, 1997), https://doi.org/10.21061/jte.v9i1.a.3.

[52] McCade, "Problem Solving: Much More than Just Design."

[53] Hill, "The Design of An Instrument to Assess Problem Solving Activities in Technology Education."

[54] Jonassen, "Instructional Design Models for Well-Structured and III-Structured Problem-Solving Learning Outcomes."

[55] Rajni Singh et al., "Research-Based Learning for Skill Development of Engineering Graduates: An Empirical Study," *Procedia Manufacturing* 31 (2019): 323–29, https://doi.org/10.1016/j.promfg.2019.03.051.

[56] Mtshali, "Critical Thinking Skills for Civil Technology Practical Assessment Tasks (PATs)."

Document Analysis

Module TECE 001

TECE 001 is a semester module for first-year technology students. This module is taught for four periods a week and focuses on the nature of technology; technology and other related subjects; the history of technology; the impact of technology on society and the environment and the technology design process.

Question 1: Describe the relationship between technology and science.
Students should be able to explain the relationship between the two subjects. They should first define each subject and identify the relationship. An explanation is the appropriate critical thinking skill required in this instance because it signifies reasoning skills before making the final decision about what to believe or do.[57] Furthermore, explanation enables students to, inter alia, explain the evidence, reasons, methods, assumptions and opinions.

Question 2: Explain how technology was developed during the period of the Renaissance, the Age of Exploration, the Industrial Revolution, and the 19th century.
By explaining the developments in each period, students demonstrate an understanding of facts and give descriptions. This question emphasises lower-order thinking, and as a result, students are not encouraged to analyse and evaluate information.

Question 3: Describe the design process as outlined in the Curriculum and Assessment Policy Statement (CAPS).
The question requires students to recall the process and show the aspects of each design process. This indicates that the questions focus on lower-order thinking as students are merely required to recall facts and basic concepts. Students were not encouraged to either apply inductive or deductive reasoning skills.[58]

Module TECE 002

TECE 002 is a semester module for second-year technology students. This module is taught for four periods a week and focuses on structures such as earthworks, road engineering, dams, and bridges.

Question 1: Explain what you understand by the following notation: 12Y16-02-180B2; describe the following specifications related to steel angle: 48 x 48 x 3; describe using a simple diagram three types of bonds; briefly explain the reason(s) why certain structures carry more load than its own weight, and if a 60 kg person stands on a table: what load is the table carrying.
Students are instructed to explain the notion 12Y16-02-180B2 and the specification 48 x 48 x 3, which prompted them to interpret this information. According to Facione, interpretation skills are applied to examine the clear meaning and significance of the given information.[59] Accurate interpretation relies on students' understanding of the context of the information given and the purpose that the information is intended to serve.

Question 2: Using a practical example, distinguish between framed and shelled structures; describe the three things that have an effect of force on a structure; describe the different types of force that structures are subjected to.
To distinguish between framed and shelled structures, students are required to demonstrate the ability to examine and break information into parts by identifying motives and causes. This question enabled students to either apply analytical skills or deductive reasoning. Analytical skills enable students to

[57] Facione, *Critical Thinking: What It Is and Why It Counts* .
[58] Facione, *Critical Thinking: What It Is and Why It Counts*.
[59] Facione, *Critical Thinking: What It Is and Why It Counts*.

recognize the elements of a context and examine the way in which the elements work together.[60] Deductive reasoning skills support students to make a decision through clearly defined contexts where, amongst others, rules, operating conditions, core beliefs and procedures utterly determine the results.

Question 3: State six things that must be considered when designing a bridge; distinguish between a suspended and cable-stayed bridge using a simple diagram; how are piers different from embankments in terms of support functions? Describe three functions of any bridge bearing; explain why expansion joints are necessary for bridge decks.
Stating six things that must be considered when designing a bridge does not prompt students to exhibit the skills required to either analyse, interpret, or evaluate information. It is a mere recalling of basic concepts. In addition, distinguishing between a suspended and stayed bridge in this context indicates the ability to compare.

Question 4: Discuss three functions of a bridge; describe your understanding of these types of bridges, i.e. beam, arch, suspended, and cantilever using the simple sketches; describe three factors that need to be considered when designing a bridge, and determine the structural stability of the bridge.
The action verb 'discuss' is located in 'creating' in which students are required to demonstrate the ability to compile elements in a new pattern or suggest alternative solutions. However, this verb is rather inappropriate in this context because students are asked to discuss three functions of a bridge, yet this is only awarded three marks. In this instance, the correct action verb should be to 'list' or 'name' three functions of a bridge. In addition, students are asked to discuss three factors that need to be considered when designing a bridge, to which six marks are allocated. Basically, each factor constitutes two marks. Also, the action verb 'discuss' is inappropriate here as the relevant verb would be 'describe' or 'name'.

Module TECE 003
TECE 003 is a semester-year module for third-year technology students. This module addresses Mechanical Systems and Control, putting emphasis on clutches, brakes, pumps and elevators.

Question 1: What are the functions of a clutch system in a motor vehicle? Differentiate between a coil spring, coil spring clutch, and diaphragm clutches; explain the functions of the components of a clutch system viz. flywheel; pressure plate; clutch disc torsion springs; and clutch-input shaft; explain the two most possible causes of clutch problems (slippage and clatter, noise, and vibrations).
The question that begins with the action verb 'what' prompts students to remember, which reflects lower-order thinking. Secondly, students were asked to differentiate between specific types of clutches. Students were not allowed to demonstrate the ability to present and justify their views and thereafter make a judgement. This question prompts lower-order thinking unless the question is framed in such a way that students analyze the functions of different components of the clutch. The last question asked students to explain the two most possible specific causes of clutch problems. However, this question prompted students to draw a conclusion from reasons and evidence that substantiate the possible causes of the clutch problems.[61] Evaluative reasoning skills enable students to examine the credibility of the source of information and claims that are made.

Question 2: Discuss the three main factors that are governed by the amount of friction developed in a breaking system; describe the types of input and output motions produced at the cylinder; state the types of levers used on a brake pedal; calculate the force required on the brake pedal to produce a force of 600 N on the brake cylinder, and describe three functions of friction in a car braking process.
This question does not prompt students to demonstrate creative skills and this indicates that the action verb 'discuss' is inappropriate in this context. Be that as it may, three marks were allocated to this

[60] Facione, *Critical Thinking: What It Is and Why It Counts*.
[61] Facione, *Critical Thinking: What It Is and Why It Counts*.

question, which means that each factor that the students discuss receives three marks. In answering this question, students demonstrate the ability to, inter alia, recall facts and ideas, and give descriptions, but this reflects lower-order thinking. The second question asked students to state the types of levers used on a brake pedal. The third question also requires students to calculate the force required on the brake pedal. The question elicited critical thinking skills. The last question asked students to describe three functions of friction in a car braking system. This question elicits lower-order thinking.

Question 3: Describe five specifications you would consider when designing an elevator hoisting system; calculate (a) the mechanical advantage of the pulley system, (b) the velocity ratio of the pulley system, (c) the efficiency of the pulley system, (d) explain the reasons why pulley systems are not 100% efficient; describe three different types of operations.
The question requires students to, inter alia, demonstrate an understanding of facts and give descriptions. This question elicits lower-order thinking. The next question asked students to calculate mechanical advantage, velocity ratio, and efficiency. However, after calculating the mechanical advantages, velocity ratio, and efficiency, students were not instructed to draw conclusions or determine the validity of the results obtained. The last question asked students to explain the reasons why pulley systems are not 100% efficient. This indicates that after students have demonstrated their understanding of facts and ideas, they are given an opportunity to present and justify their views with the intention of drawing conclusions. This question elicited critical thinking skills.

Module TECE 004
TECE 004 is a semester module for fourth (final) year technology students. The module focuses on Electrical Systems and Control.

Question 1: Students were given a circuit diagram to identify components; modify the circuit diagram to suit two functions of a specific component; explain the reasons why this specific component should always be connected in series with additional components; briefly discuss the operation of the given circuit diagram.
Though this question elicits critical thinking skills, it elicits lower-order thinking, particularly when students are only required to identify components such as resistors and switches in the circuit diagram. Secondly, students were instructed to modify the circuit diagram. In essence, when students demonstrate the ability to modify a circuit diagram, this reflects the ability to develop alternative solutions. The third question instructed students to explain the reasons why a specific component should always be connected in series. Students were required to explain why a specific component must always be connected in series. This question prompted students to evaluate, provide an explanation and apply deductive reasoning. Sound explanation skills can lead to a high-quality evaluation by providing the evidence, reasons, methods, criteria, or assumptions in relation to claims made and conclusions drawn (Facione, 2020).[62] Students are required to substantiate the reasons why certain components are always connected in a series.

Question 2: Explain the concept design and its implications in technology; give an illustrated example of common features shared by all activities grouped under design; distinguish between the study of ergonomics and anthropometrics in design; compile any four ergonomics details designers would require before designing a smartphone; and draw a concept map on the nature of the design process.
Explaining the concept and its implication in technology requires deductive reasoning skills. Deductive reasoning advances a precisely defined context that is assumed to be true based on the set of beliefs that led to the dependable conclusion. Thus, students should explicitly define the concept design and its implications in technology and provide a concept map. This question elicits critical thinking skills.

[62] Facione, *Critical Thinking: What It Is and Why It Counts*.

Question 3: Students were given an article to study and answer questions on it thereafter. The article was about the load shedding of electrical energy in South Africa. Briefly explain what the article is all about; what advice will you give to the South African society at large to save energy? How could load shedding be avoided in the future?
Providing students with an article empowers them to be critical readers, particularly when given opportunities to analyse information. This question enables students to analyse, interpret, infer, evaluate, provide an explanation, and apply inductive reasoning and deductive reasoning.

Question 4: Students were instructed to draw the truth table using the logic diagram below; determine the expression expected at Z; use Boolean theorems to simplify the expression at Z; draw a diagram for the simplified expression at Z.

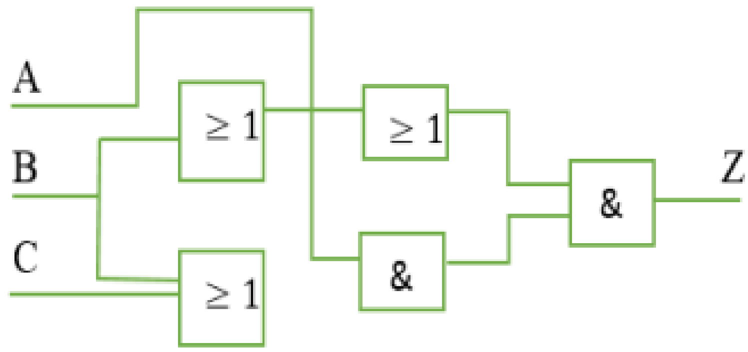

Figure 1: Diagram

Critical thinking skills involve cognitive skills, particularly when one is supposed to examine a diagram and represent the diagram in the form of a drawing. Drawing on this question involves the ability to analyse and compile information. Students are expected to determine the expression at Z within the logic diagram. This exercise prompts students to present and justify their views and successively draw conclusions. This question elicits critical thinking skills. The third question instructs students to use Boolean theorems to simplify the expression at Z. This question compels students to apply previously learned theory.

SUMMARY

Critical thinking skills involve the ability to interpret, analyse, evaluate, make inferences, reflect, and reason proficiently.[63] These skills enable students to make informed decisions and effectively influence humanity.[64] During the implementation of critical thinking skills, students are introduced to real-life problem-based learning scenarios[65] which require them to work collaboratively together to

[63] Huda Qasim Mazal and Suhad Abdul Ameer Abbood, "The Divergent Thinking Skills of Secondary School Students," *Annals of the Romanian Society for Cell Biology* 25, no. 7 (2021): 255–72.
[64] Bui Phuong Uyen, Duong Huu Tong, and Nguyen Ngoc Han, "Enhancing Problem-Solving Skills Of 8th-Grade Students in Learning the First-Degree Equations in One Unknown," *International Journal of Education and Practice* 9, no. 3 (2021): 568–87, https://doi.org/10.18488/journal.61.2021.93.568.587.
[65] Meiqian Wang and Xudong Zheng, "Using Game-Based Learning to Support Learning Science: A Study with Middle School Students," *The Asia-Pacific Education Researcher* 30, no. 2 (April 13, 2021): 167–76, https://doi.org/10.1007/s40299-020-00523-z.

identify problems incorporated in the given scenarios,[66] find solutions together and discuss the implications of their findings relative to the content they learnt about.[67]

It is therefore imperative to support students to develop critical thinking skills and generate assessment instruments that suit different contexts.[68] Currently, there is no appropriate critical thinking assessment instrument that suits the South African context to which local universities could apply.[69] Summative assessment provides an overall picture of the students' progress at the end of the semester or learning experience. Essentially, summative assessment reflects the scope of what was taught during the learning experience. As a result, if technology teachers put emphasis on critical thinking skills, this should reflect in the summative assessment. The findings of this study reveal that technology lecturers in the selected university, to a certain degree, assessed critical thinking skills. These technology lecturers train students that are expected to foster critical thinking skills after completing the programme.

CONCLUSION

The nature of questions set for summative assessment unsuccessfully stimulates students to apply analytical reasoning, interpret information, draw conclusions, evaluate information and utilise inductive or deductive reasoning. South African universities should develop the appropriate assessment instrument for critical thinking and employ it in assessing students accordingly. Society thus relies on universities to instil critical thinking skills so that students are able to find technological solutions. Further research should be undertaken to determine the extent to which lecturers stimulate students to develop critical thinking skills during formative assessment.

BIBLIOGRAPHY

Airasian, Peter W, and Helena Miranda. "The Role of Assessment in the Revised Taxonomy." *Theory into Practice* 41, no. 4 (2002): 249–54.

Ary, Donald, Lucy Cheser Jacobs, and Chris Sorensen. *Introduction to Research in Education*. Belmont: Wadsworth Cengage Learning, 2012.

Berzenski, Sara R, Ryan LaSalle-Castro, Ana Kamille Marcelo, and Tuppett M Yates. "The Development of Divergent Thinking despite Poverty: Moderating Factors." *Cognitive Development* 64 (2022): 101244.

Black, Paul. "Formative Assessment in the Learning and Teaching of Design and Technology." *Design and Technology Education: An International Journal* 13, no. 3 (2008).

Brinkmann, Svend, and Steinar Kvale. *Doing Interviews*. Vol. 2. Sage, 2018.

Cohen, Louis, Lawrence Manion, and Keith Morrison. *Research Methods in Education*. Eighth edition. | New York: Routledge, 2018.: Routledge, 2007. https://doi.org/10.4324/9781315456539.

Davari, Farzad Vaghef, Farzad Teymouri, Hadi Ahmadi Amoli, Helia Mojtabavi, Amirsina Sharifi, Farshid Alaeddini, Mohammad Ashouri, Hossein Zabihi, Ghazal Shariatpanahi, and Mohammadreza Zafarghandi. "Problem-Based Learning as an Effective Method for Teaching Theoretical Surgery Courses to Medical Students." *Journal of Education and Health Promotion* 10 (2021).

Department of Basic Education. *Curriculum and Assessment Policy Statement Grades R-12, First Additional Language*. Pretoria: Department of Basic Education, 2011.

Dunne, Gerry. "Beyond Critical Thinking to Critical Being: Criticality in Higher Education and Life." *International Journal of Educational Research* 71 (2015): 86–99.

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[66] Sara R Berzenski et al., "The Development of Divergent Thinking despite Poverty: Moderating Factors," *Cognitive Development* 64 (2022): 101244.

[67] Farzad Vaghef Davari et al., "Problem-Based Learning as an Effective Method for Teaching Theoretical Surgery Courses to Medical Students," *Journal of Education and Health Promotion* 10 (2021).

[68] Nitu Sharma and Rajni Dhingra, "Divergent Thinking Skills Among Primary School Students in Jammu: Perception of School Personnel," *International Journal of Current Research Key Words* 9, no. 9 (2017): 57751–55.

[69] Mtshali, "Critical Thinking Skills for Civil Technology Practical Assessment Tasks (PATs)."

Ennis, Robert H. “Critical Thinking Assessment.” *Theory Into Practice* 32, no. 3 (June 1993): 179–86. https://doi.org/10.1080/00405849309543594.
Ennis, Robert Hugh, and Eric Edward Weir. *The Ennis-Weir Critical Thinking Essay Test: An Instrument for Teaching and Testing*. Midwest Publications, 1985.
Facione, P.A. *Critical Thinking: What It Is and Why It Counts*. Insight Assessment, Pearson Education, 2015. https://www.insightassessment.com/article/critical-thinking-what-it-is-and-why-it-counts.
Facione, Peter. “The California Critical Thinking Skills Test: College Level Experimental Validation and Content Validity,” January 1, 1990.
Halpern, Diane F. “Assessing the Effectiveness of Critical Thinking Instruction.” *The Journal of General Education* 50, no. 4 (2001): 270–86.
———. *The Nature and Nurture of Critical Thinking.* Cambridge University Press, 2007.
Hart, Claire, Cliff Da Costa, Daryl D’Souza, Amanda Kimpton, and Jelena Ljbusic. “Exploring Higher Education Students’ Critical Thinking Skills through Content Analysis.” *Thinking Skills and Creativity* 41 (2021): 100877.
Hill, Roger B. “The Design of An Instrument to Assess Problem Solving Activities in Technology Education.” *Journal of Technology Education* 9, no. 1 (September 1, 1997). https://doi.org/10.21061/jte.v9i1.a.3.
Howe, Edward R. “Canadian and Japanese Teachers’ Conceptions of Critical Thinking: A Comparative Study.” *Teachers and Teaching* 10, no. 5 (2004): 505–25.
Insight Assessment. “California Critical Thinking Test (CCTST),” 2021. https://www.insightassessment.com/.
Janse van Rensburg, Joalise, and Willem Rauscher. “Strategies for Fostering Critical Thinking Dispositions in the Technology Classroom.” *International Journal of Technology and Design Education* 32, no. 4 (September 5, 2022): 2151–71. https://doi.org/10.1007/s10798-021-09690-6.
Jonassen, David H. “Instructional Design Models for Well-Structured and III-Structured Problem-Solving Learning Outcomes.” *Educational Technology Research and Development* 45, no. 1 (1997): 65–94.
Jones, Alister, and Judy Moreland. “Enhancing Practicing Primary School Teachers’ Pedagogical Content Knowledge in Technology.” *International Journal of Technology and Design Education* 14, no. 2 (May 2004): 121–40. https://doi.org/10.1023/B:ITDE.0000026513.48316.39.
Ku, Kelly Y L. “Assessing Students’ Critical Thinking Performance: Urging for Measurements Using Multi-Response Format.” *Thinking Skills and Creativity* 4, no. 1 (2009): 70–76.
Maree, Kobus. *First Steps in Research*. Hatfield: Van Schaik Publishers, 2014.
Mazal, Huda Qasim, and Suhad Abdul Ameer Abbood. “The Divergent Thinking Skills of Secondary School Students.” *Annals of the Romanian Society for Cell Biology* 25, no. 7 (2021): 255–72.
McCade, Joseph. “Problem Solving: Much More than Just Design.” *Journal of Technology* 2, no. 1 (1990).
Merriam, Sharan B. *Qualitative Research and Case Study Applications in Education. Revised and Expanded from" Case Study Research in Education."*. ERIC, 1998.
Meyer, L W, and P G Warnich. “Outcomes-Based Education and Outcomes-Based Assessment in South African Schools: The Way Forward.” *Meyer, L, Lombard, K, Warnich, P & Wolhuter, C. Outcomes-Based Assessment for South African Teachers, Van Schaik’s Publishers: Pretoria*, 2010, 161–73.
Mtshali, Thokozani I. “Critical Thinking Skills for Civil Technology Practical Assessment Tasks (PATs).” *World Transactions on Engineering and Technology Education, WIETE* 18, no. 2 (2020): 237–41.
Norris, Stephen P. “Can We Test Validly for Critical Thinking?” *Educational Researcher* 18, no. 9 (1989): 21–26.

Paul, R, and L Elder. "The Miniature Guide to Critical Thinking Tools and Concepts." Foundation for Critical Thinking Press: Tomales, CA, 2007.
Paul, Richard, and Gerald M. Nosich. "A Model for the National Assessment of Higher Order Thinking." Foundation for Critical Thinking, 4655 Sonoma Mountain Road, Santa Rosa, CA 95404 ($3)., 1992.
Phuong Uyen, Bui, Duong Huu Tong, and Nguyen Ngoc Han. "Enhancing Problem-Solving Skills Of 8th-Grade Students in Learning the First-Degree Equations in One Unknown." *International Journal of Education and Practice* 9, no. 3 (2021): 568–87. https://doi.org/10.18488/journal.61.2021.93.568.587.
Renaud, Robert D, and Harry G Murray. "A Comparison of a Subject-Specific and a General Measure of Critical Thinking." *Thinking Skills and Creativity* 3, no. 2 (2008): 85–93.
Sarantakos, S. "Social Research." London: Macmillan International Higher Education, 2012.
Sermeus, Jan, M. De Cock, and J. Elen. "Critical Thinking in Electricity and Magnetism: Assessing and Stimulating Secondary School Students." *International Journal of Science Education* 43, no. 16 (November 2, 2021): 2597–2617. https://doi.org/10.1080/09500693.2021.1979682.
Sharma, Nitu, and Rajni Dhingra. "Divergent Thinking Skills Among Primary School Students in Jammu: Perception of School Personnel." *International Journal of Current Research Key Words* 9, no. 9 (2017): 57751–55.
Singh, Rajni, Devika, Christoph Herrmann, Sebastian Thiede, and Kuldip Singh Sangwan. "Research-Based Learning for Skill Development of Engineering Graduates: An Empirical Study." *Procedia Manufacturing* 31 (2019): 323–29. https://doi.org/10.1016/j.promfg.2019.03.051.
Wang, Meiqian, and Xudong Zheng. "Using Game-Based Learning to Support Learning Science: A Study with Middle School Students." *The Asia-Pacific Education Researcher* 30, no. 2 (April 13, 2021): 167–76. https://doi.org/10.1007/s40299-020-00523-z.
Wilberding, Erick. *Socratic Methods in the Classroom: Encouraging Critical Thinking and Problem Solving Through Dialogue (Grades 8-12)*. Routledge, 2021.
Wiliam, Dylan. "Assessment: The Bridge between Teaching and Learning." *Voices from the Middle* 21, no. 2 (2013): 15.
———. "What Is Assessment for Learning?" *Studies in Educational Evaluation* 37, no. 1 (March 2011): 3–14. https://doi.org/10.1016/j.stueduc.2011.03.001.

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