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Knowledge and cognitive process dimensions of Technology teachers' lesson objectives

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A clearly stated lesson objective is considered an essential component of a well-planned lesson. Many teachers of Technology, a relatively new subject in South African schools, teach Technology with rather limited training both in content and methodological approaches. This study sought to investigate and classify lesson objectives framed or implied by teachers in their lesson plans according to knowledge and cognitive process dimensions. The two-dimensional Taxonomy Table introduced by Krathwohl was adapted for Technology and formed the framework for this study. It was found that most of the directly stated objectives are directed to the lower level of the cognitive process dimension and address mainly factual knowledge, while no activities or lesson components address meta-cognitive knowledge. Some lesson objectives inferred from planned assessment activities placed higher demands on learners' cognitive domain. A recommendation flowing from the study is that, during pre-service training and in-service teacher support processes, the importance of clear lesson objectives should be emphasised and that assessments planned for such lessons should closely match the lesson objectives. Further research is also needed on the reasons why low cognitive demands are made in the teaching of Technology.

Keywords: Bloom's cognitive taxonomy; cognitive process dimensions; higher cognitive skills; knowledge dimensions; Krathwohl's two-dimensional taxonomy; lesson objectives, technology education

Introduction

Developing economies, including South Africa, are challenged to become competitive in knowledge-based and technological domains. Currently, South Africa has a shortage of high level skills which, inter alia, inhibits the county's growth rate (Breier, 2009) to the extent that Du Toit and Roodt (2009:109) describe it as "one of the worst capacity and scarce skills crises in years". Global trends exacerbate this situation as many developing countries lose highly skilled workers produced by them to countries that can, for example, pay more and offer improved occupational and living conditions (Breier, 2009; Porter, 1990). Key sectors such as engineering and other technological fields experience shortages due to the increased demand for higher-level knowledge and cognitive skills. In South Africa an attempt has been made to address the technological and higher-cognitive skills shortage by the introduction of Technology as a subject in South African schools since 1997. A review of the achievements of this introduction has become relevant. Should the introduction of the subject were to be successful, similar attempts may be made in other countries with developing economies.

Technology was introduced into the South African school curriculum in recognition of the need to produce more engineers, technicians and artisans and thus to be a vehicle to develop readiness for a competitive and technology-driven economy (Department of Basic Education, 2011). Bloch (2007) avers that it is due to the poor quality in the education system that South Africa is not able to meet the requirement of adequate skills for growth: he ascribes this failure to the poor quality of teaching and teacher support. Bloch (2007) is especially concerned about teachers' inadequate subject knowledge. Teachers' poor grasp of the subjects they teach (Metcalfe, 2008) results in erroneous presentation of content and concepts, which results in learners leaving school being ill-prepared. In turn this affects the country's economy negatively (Mda, 2009).

When Technology was introduced as a school subject, teachers of Woodwork, Metalwork, Home Economics and Industrial Arts, with limited training in the content and methodological approaches of technology education, were expected to teach Technology (Van Niekerk, Ankiewicz & De Swardt, 2010). Insufficient knowledge of the technological process, procedural knowledge and scientific content knowledge required to teach Technology leads to deficiencies in teachers' approaches to content and teaching methodologies (Van Niekerk et al., 2010).

The Department of Education (DoE) (2003) has reported widespread lack of content knowledge and poor manual skills among Technology teachers. As a purpose of Technology is to develop learners' creative and critical thinking skills (Department of Basic Education, 2011), it should be investigated whether these higher-order thinking skills are addressed in the classroom. This study, therefore, sought to investigate the knowledge and cognitive process dimensions of lesson objectives framed by Technology teachers in their lesson plans, or inferred from the assessment tasks described in their lesson plans as a representation of current practices. To this end the cognitive and knowledge taxonomy of Krathwohl (2002) was adapted to analyse the practices of teachers of Technology in formulating and assessing lesson objectives.

Technology education: contextual background

Technology education was first introduced in 1997 in the General Education and Training band (Grades R–9) as part of the outcomes-based education (OBE) curriculum. OBE, according to the DoE (2002), is a way of teaching and learning which makes it clear what learners are expected to achieve as it requires the setting of outcomes to be achieved at the end of the process. The 1997 OBE curriculum was reviewed in 2000 which led to the first curriculum revision: the *Revised National Curriculum Statement (RNCS) Grades R–9* and the *National Curriculum Statement (NCS) Grades 10–12* (DoE, 2002). In 2009 the curriculum was again reviewed and the *National Curriculum Statement Grades R–12* (Department of Basic Education, 2011) was introduced. In the latter revision curricula for specific subjects are described in documents named *Curriculum and Assessment Policy Statements (CAPS)* (Department of Basic Education, 2011:3).

According to the DoE (2002) the purpose of Technology education in South Africa is to contribute towards learners' technological literacy, which the DoE defines as "the ability to use, manage and assess technology" (DoE, 2002:66). Technology should stimulate learners to be innovative and develop their creative and critical thinking skills: these skills should provide a solid foundation for several Further Education and Training (FET) subjects (Grades 10–12) as well as for the world of work (Department of Basic Education, 2011).

Table 1 provides a comparative summary of the learning outcomes stated in the RNCS (DoE, 2002), the specific aims of the NCS (Department of Basic Education, 2011), and the topics and content areas of the 2002 and 2011 Technology curriculums.

Table 1 shows that for Technology the learning outcomes of the RNCS (DoE, 2002) have been rephrased to the specific aims of the NCS (Department of Basic Education, 2011). The similarity retained in the purpose of the curriculum through this shift is sufficient to allow for the differences to be neglected, particularly when it is noted that the detailed content has not changed. It is, therefore, assumed that although the study used lesson plans based on the RNCS (DoE, 2002), the results will also apply to the NCS (Department of Basic Education, 2011).

Literature review

The concept: lesson objective

Researchers describe lesson objectives differently. Lemov (2010) takes a lesson objective to mean what learners need to know or be able to do at the end of the lesson. Koepke and Cerbin (2009) refer to a clear and measureable explanation of what learners will be able to do after they have been presented with instruction as an instructional objective. Ricker, Brown, Leeds, Leeds, Bonar Bouton and Volgstadt (1998) state that a measurable objective should contain four pieces of information (which they characterise as "ABCD"): audience/learner characteristics, behaviour/action to be demonstrated, conditions/circumstances of the lesson environment and degree/or criteria for acknowledging achievement. Mager (1991:5) defines a lesson objective as a "description of a performance you want learners to be able to exhibit before you consider them competent". An objective specifies the end result of an instruction rather than its process. A lesson objective as conceptualised in this study means any behavioural action that is specific and observable or measureable and is required to be demonstrated by learners after receiving instruction.

Hofstee (2006) emphasises that from the outset, in every activity, participants clearly indicate what they want to achieve at the end of the activity. This emphasises that clarity of purpose is important in every activity, *inter alia*, lesson design and presentation. The purpose may be overtly stated, where the lesson objective is clearly mentioned, or covertly stated, where the lesson objective can be inferred from the description of assessment activities in a lesson plan.

Anderson, Krathwohl, Airasian, Cruikshank, Mayer, Pintrich, Raths and Wittrock (2001:265) note that educational objectives indicate that the learner "should be able to do something (verb) to or with something (noun)". Objectives should, therefore, reflect a verb-noun relationship.

Classifying objectives in a framework or taxonomy may be helpful to, for example, determine the congruence of educational objectives in a curriculum or to examine the breadth and depth of a course (Krathwohl, 2002). Bloom, Engelhart, Furst, Hill and Krathwohl (1956) published such taxonomy of the cognitive domain. The taxonomy was conceptualised to facilitate

Table 1 Summary of the Technology curriculums: the RNCS compared with the NCS

Learning outcomes (LO): RNCS	Specific aims (SA): NCS (CAPS)	Topics and content of both curricula
LO 1: The learner will be able to apply technological processes and skills ethically and responsibly using appropriate information and communication technologies.	SA 1: Develop and apply specific design skills to solve technological problems.	The design process: Investigation Design Making Evaluation Communication
LO 2: The learner will be able to understand and apply relevant technological knowledge ethically and responsibly.	SA 2: Understand the concepts and knowledge used in Technology education and use them responsibly and purposefully.	* Structures * Processing * Mechanical and electrical systems and control
LO 3: The learner will be able to demonstrate an understanding of the interrelationships between science, technology, society and the environment.	SA 3: Appreciate the interaction between people's values and attitudes, technology, society and the environment.	Technology, society and the environment: * Indigenous technology * Impact of technology * Bias in technology

Sources: Department of Education (2002) and Department of Basic Education (2011) the exchange of test items between various universities in order to create banks of items which measure the same educational objective (Krathwohl, 2002).

Taxonomy of educational objectives: cognitive domain

The taxonomy by Bloom et al. (1956) (hereafter referred to as the original taxonomy) consists of six major categories in the cognitive domain, namely Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. These categories were ordered from simple to complex and from concrete to abstract (Krathwohl, 2002). Also, it was assumed that the taxonomy constitutes a cumulative hierarchy: the "mastery of each simpler category was prerequisite to mastery of the next more complex one" (Krathwohl, 2002:212–213).

Krathwohl (2002) notes that one of the most frequent uses of the original taxonomy is to classify curricular objectives and test items in order to show the breadth (or lack thereof) of the objectives and items across the spectrum of categories. He also points out that although objectives that involve understanding and use of knowledge (Comprehension through Synthesis categories) are considered the most important goals in education, there is "almost always" a heavy emphasis on objectives that require only recognition or recall of information (Knowledge category) (Krathwohl, 2002:213).

A major criticism against the original taxonomy has been that the Knowledge category generally supplies nouns in objectives. Yet, while the other categories are also formulated as nouns (e.g. Application and Analysis), they take the verb form (e.g. Apply and Analyse) when used in objectives (Anderson et al., 2001). The Knowledge category, on the other hand, can embody both a noun and a verb (in terms of the definition of knowledge) in an objective. This, according to Krathwohl (2002:213) brought "unidimensionality" to the framework and noted that the Knowledge category is dual in nature and is therefore different to the other categories. This difference was addressed in a revised taxonomy by allowing the noun and verb to form separate dimensions: nouns provide the basis for the knowledge dimension and verbs form the basis for the cognitive dimension (Krathwohl, 2002).

The revised taxonomy: from one to two dimensions

Anderson et al. (2001) revised the original taxonomy by making three changes, namely in emphasis, in terminology and in structure. The revision's primary focus is on how the taxonomy is used as there is a major shift from the original focus on assessment to an emphasis on the use of the taxonomy in planning the curriculum, instruction and assessment, and the alignment of these three aspects (Anderson et al., 2001).

Another prominent change from the original taxonomy is the change in terminology. Major category titles were changed to provide consistency with the way objectives are framed: Knowledge, for example, was renamed as Remember and all categories were labelled in their verb forms (e.g. Apply and Analyse) (Anderson et al., 2001).

Lastly, there were changes in structure. Anderson et al. (2001) separated the noun and verb components in the original Knowledge category. The noun component retained the label, "Knowledge", but was structured into a separate dimension consisting of four categories. The revised Knowledge dimension comprised the following categories: Factual knowledge, Conceptual knowledge, Procedural knowledge and Meta-cognitive knowledge (Anderson et al., 2001).

While the noun component of the original Knowledge category retained the label "Knowledge" in the revised taxonomy, the verb component of Knowledge was renamed Remember and replaced the Knowledge category in the original taxonomy (Anderson et al., 2001).

Another change in the structure was the order of the categories to reflect an increase in complexity. The order of the top two cognitive categories was changed, placing Create (Synthesis in the original taxonomy) as the most complex category instead of Evaluate (Evaluation in the original taxonomy) (Anderson et al., 2001). The hierarchical order of the Cognitive Process dimension of the revised taxonomy thus becomes: Remember, Understand, Apply, Analyse, Evaluate and Create (Anderson et al., 2001).

The fact that any objective can be represented in two dimensions presents the possibility of constructing a two-dimensional table, which Krathwohl (2002:215) termed the Taxonomy Table. The conceptual framework used in this study is based on Krathwohl's proposed Taxonomy Table.

Conceptual framework

The Knowledge dimension forms the vertical axis and the Cognitive Process dimension forms the horizontal axis in the Taxonomy Table. The vertical axis, constituting the rows of the Taxonomy Table, consists of the categories of the Knowledge dimension which include Factual knowledge, Conceptual knowledge, Procedural knowledge and Meta-cognitive knowledge. The horizontal axis, forming the columns of the Taxonomy Table, comprises the categories of the Cognitive Process dimension, namely Remember, Understand, Apply, Analyse, Evaluate and Create. Tables 2, 3 and 4 reflect the structure of the Taxonomy Table as we have applied it.

The intersections of the Knowledge and Cognitive Process categories form the cells in which any objective could be classified in term of their verbs (columns) and nouns (rows) (Krathwohl, 2002).

In the research reported here, lesson plans were obtained from teachers of Technology. Lesson objectives of these plans were identified in two ways: as they were stated explicitly in the plans by the teachers themselves, or as they were inferred by us from the assessment activities described in the plans.

Explicitly stated and inferred objectives from the teachers' lesson plans were framed in terms of subject matter content and a description of what was to be done with, or to, the content (Krathwohl, 2002). The subject matter content was represented by a noun or noun phrase. What was to be done with or to the content subject matter was represented by a verb or verb phrase (Krathwohl, 2002). The Technology teachers' lesson objectives were analysed and classified according to the cells of the two-dimensional Taxonomy Table using the verb-noun relationship described earlier.

Research approach

A mixed modal study was used to investigate sampled lesson objectives described by Technology teachers. Explicitly stated or inferred objectives were classified according to Krathwohl's (2002) Taxonomy Table after which the objectives in each cell were counted to establish the frequency of occurrence of objectives in each cell in a quantitative phase.

In the qualitative phase specific cases of explicit or inferred objectives were selected in order to examine the implications of the frequency of occurrences of objectives in the Taxonomy Table. Such discussion afforded the opportunity to assess the level of Technology teachers' lesson objectives in terms of knowledge and cognitive dimensions, with a critical reflection on the actual relationship between objectives, assessments and the nature of actual activities in the lesson plans.

Sampling

A limited survey was conducted to obtain 94 lesson plans from 19 Grade 9 Technology teachers in clustered schools in urban, township and rural environments of Gert Sibande, Ehlanzeni and Nkangala districts in the Mpumalanga Province. Grade 9 Technology teachers were purposefully sampled as Grade 9 is the highest grade in which Technology is a compulsory subject in South African schools. It was assumed that the cognitive challenges posed to the Grade 9 learners would be higher than those in the preceding grades. Evidence of lesson objectives addressing these higher cognitive challenges were therefore more likely to appear in the Grade 9 teachers' lesson plans.

To overcome the challenge of the large and widely dispersed population of schools in these districts (and the often near-inaccessibility of some deep rural schools) cluster sampling was used (Cohen, Manion & Morrison, 2007). Cohen et al. (2007) advise that cluster sampling allows the researcher to select a specific number of schools and limit the excessive amount of time spent travelling. Curriculum implementers (subject advisors) in those districts assisted in the identification and locations of the clustered schools. Curriculum implementers are employees of the DoE who, as subject specialists, assist teachers in schools with teaching approaches, equipment and assessments on a continual basis within the districts, and are thus acquainted with schools.

Explicitly written lesson objectives were obtained from the lesson plans. Where lesson plans did not have explicitly stated lesson objectives, assessment activities from these lessons were used to infer lesson objectives. A total of 84 explicitly stated and inferred lesson objectives were separately assigned to cells in the Taxonomy Table.

Analysis methodology

In the quantitative phase each lesson objective was classified according to the knowledge and cognitive levels of the Taxonomy Table. In the lesson objective, the verb or verb phrase represented the cognitive level while the noun or noun phrase represented the content or subject matter knowledge level. Choices were made according to the highest level represented by the verbs and nouns. The results of the classification were tabled and counted to establish the frequency of occurrence of each knowledge and cognitive level in the sampled lesson objectives.

In the qualitative analysis a selection of examples of lesson objectives is discussed in order to show how each lesson objective was classified in the indicated cell. This was done for both explicit and inferred lesson objectives.

Content validity was achieved by using Krathwohl's (2002) Taxonomy Table as the conceptual framework to guide the study. The choice of the Taxonomy Table as a framework to this study was aided by its use by Ferguson (2002) and Byrd (2002) who have shown its potential for teachers' reflection on assessment and improvement of classroom practice. Reliability was enhanced by providing qualitative examples of lesson objectives, showing how they were assigned to the cells of Krathwohl's (2002) Taxonomy Table.

Credibility, according to Ary, Jacobs, Sorensen and Razavieh (2009), relates to the truthfulness of the findings. The credibility of the study was enhanced through structural corroboration (using more than one method) and through member checks by allowing participants to verify the accuracy of the interpretations in a focus group discussion with some of the teachers who had contributed their lesson plans.

Transferability of this study lies with the practitioners and readers (Ary et al., 2009). For that purpose, sufficient contextual information was given about where the data were collected. Confirmability was enhanced by guarding against the researcher's personal values, theoretical inclinations, bias, own predispositions and preferences swaying the conduct of the research and the findings by discussing lesson objectives on the basis of how they were framed by the teachers. In addition, a complete audit trail is available for other researchers to investigate the data and context used in this study.

Results and discussion

Each explicitly stated and inferred lesson objective was assigned to a cell in Krathwohl's (2002) Taxonomy Table using the verb or verb phrase to indicate the cognitive level, and the noun or noun phrase to indicate the content (knowledge level). The tables that follow present the frequency of these classifications of explicitly stated lesson objectives and inferred lesson objectives.

Table 2 shows that three explicit lesson objectives were aimed at remembering factual (the most basic) knowledge. Five lesson objectives required learners to demonstrate an understanding of factual knowledge and two objectives intended an understanding of conceptual knowledge. These lower-level lesson objectives seem to indicate that the teachers merely wanted learners to retain and comprehend what they had learnt.

The paucity of lesson objectives that required higher-order

Table 2 Frequency of the explicitly stated lesson objectives within the Cognitive Process and Knowledge dimensions ($N = 22$)

Knowledge dimension	Cognitive process dimension						Frequency of the knowledge dimension
	Remember	Understand	Apply	Analyse	Evaluate	Create	
Factual	3	5		3			11(50%)
Conceptual		2		4	1		7 (32%)
Procedural			2	1		1	4 (18%)
Meta-cognitive							0 (0%)
Frequency of the cognitive dimension	3(14%)	7(32%)	2(9%)	8(36%)	1 (5%)	1(5%)	

thinking and complex knowledge is disappointing. Only one objective required learners to evaluate using conceptual knowledge and one objective involved creation using procedural knowledge.

The aggregated frequency of the knowledge dimensions indicates that most objectives were formulated to favour Factual knowledge (50%) and Conceptual knowledge (32%), which reflects the lower levels of simple Technology content. Only 18% of objectives for Procedural knowledge were above these levels, and no objectives expressed a need for Meta-cognitive knowledge.

The incidence of formulation of lesson objectives by the teachers decreased as the knowledge demand increased, with no objectives requiring meta-cognition or actual explanation or reflection by learners about how and why they made their choices.

Again, the low frequency of Create and Evaluate, which are the highest levels in the cognitive process, confirm that less is done by Technology teachers at these levels.

However, the fairly high frequency (36%) of Analyse is startling, although it was noted that this kind of analysis happened mostly on the Factual and Conceptual knowledge levels.

Examples of how five explicitly stated lesson objectives were classified within the Taxonomy Table as a conceptual framework of this study are presented next. The frequency presented in Table 2 was derived from these classifications. Lesson objectives are presented as formulated by the Technology teachers.

(i) Lesson objective classified under "remember" and "factual knowledge":
Learners will be able to recognise the impact of technology development on the quality of peoples' lives [sic].

Verb: *recognise* – Recognising is a subcategory of Remember in the Cognitive Process dimension.

Noun phrase: *the impact of technology development on the quality of peoples' lives [sic]*. This knowledge is addressed in the context of Learning Outcome 3 which deals with the topic of the impact of technology. The assessment standard requires learners to recognise and identify the impact of technological developments on the quality of people's lives and on the environment in which they live, and suggests strategies for reducing any undesirable effects (DoE, 2002). In the lesson objective learners were simply required to recognise those impacts of technological development; hence it was Factual knowledge.

(ii) Lesson objective classified under Analyse and Conceptual:
Learners will be able to find out which shape holds the greatest load.

Verb phrase: *find out* – Organising is a subcategory of Analyse which includes finding out (or determining) how elements fit or function within a structure.

Noun phrase: *which shape holds the greatest load*. This lesson objective relates to structures in Learning Outcome 2 and deals with the assessment standard which reads, "analysis (no calculations) the effect of different loads" (DoE, 2002:47). Different concepts of shapes are to be analysed; hence, Conceptual knowledge.

(iii) Lesson objective classified under Apply and Procedural:
Learners will be able to demonstrate knowledge of indigenous preservation methods.

Verb: *demonstrate* – Executing is a subcategory of Apply which involves applying (carrying out) a procedure in a given situation.

Noun phrase: *knowledge of indigenous preservation methods*. Learning Outcome 3 includes the topic of indigenous technology and culture, where learners deal with methods of preservation, which is primarily Procedural knowledge.

(iv) Lesson objective classified under Evaluate and Conceptual
Learners will be able to experiment with beam bridges and find out how lengths and materials affect bridges.

Verb: *Experiment with…and find out* – Checking is a subcategory of Evaluate and involves testing and monitoring.

Noun phrase: *beam bridges, different lengths of materials*. This addresses the curriculum requirement relating to structures in Learning Outcome 2 where the related assessment standard states: "demonstrates knowledge and understanding of structures – properties of materials that affect their performance in structures" (DoE, 2002:47).

The verb phrases *experiment with…and find out* are synonymous with evaluate, assess and conduct research, hence falls under Evaluate, while *beam bridges* and *different lengths* are concepts. Determining how different lengths of a material can affect its performance in a beam bridge requires of learners to carry out evaluation and also some analysis in order for them to be able to tell how changing lengths affect the bridge.

(v) Lesson objective classified under Create and Procedural
On completion of this lesson learners will be able to make their own hydraulic system + lift model and how to operate a hydraulic system.

Verb: *Make…and operate* – Constructing is a subcategory of Create, which involves putting elements together to form a functional product.

Noun phrase: *hydraulic system + lift model*. This addresses the curriculum requirement which deals with mechanical systems and control in Learning Outcome 2. The related assessment standard states: "demonstrates knowledge and understanding of interacting mechanical systems and sub-systems" (DoE, 2002: 49). During the making stage learners will be creative and will follow certain procedures. The following questions were addressed in the introduction to this lesson: "how to connect syringes with the plastic tubes"; "how to collect water" and "how the force is transmitted through liquid". In this lesson learners were required to make a hydraulic system by completing two activities that required investigating hydraulics and the effect of piston size. Resources used were syringes, plastic tubes, cardboard and glue. Although this might have raised the level of creativity, learners were not allowed to use their own materials in making their models. Learners were simply required to apply instructions as recipes and to use the provided resources, which would limit the learners' level of creativity to application. However, to some extent the investigative activity might have assisted learners to be creative in making their own hydraulic model. The highest cognitive level Create may thus be acceptable, although it may be argued that Apply remains dominant. The highest level potentially achieved was assigned and thus this objective was counted with Create, rather than Apply and consequently care must be taken with interpretation of these higher levels.

In each case presented here the lesson plans provided insufficient information and it was difficult to establish whether learners were taught at the higher cognitive levels implied by the objective statements.

Most of the lesson plans did not include explicitly stated lesson objectives, but lesson objectives were inferred from assessment activities. The analysis of the inferred lesson objectives is presented in Table 3.

Table 3 shows 18 objectives aimed at remembering factual knowledge, which is unfortunate as this indicates a tendency to teach at the lower cognitive and knowledge dimensions. It is, however, encouraging that 12 lesson objectives involved creating using procedural knowledge.

Table 3, as is the case in Table 2, shows that aspects of the Meta-cognitive level are not taught. Procedural knowledge records a substantial percentage of 32% and its lesson objectives clustered under Create. Once more, the lesson plans did not provide sufficient information. This might imply that learners completed projects that required creativity, but that they were not properly guided by the teacher, nor were explicit lesson objectives provided.

Remember recorded the highest percentage, followed by Create and Analyse, while Apply did not record anything. The Cognitive Process dimension does not flow from lower-order to higher-order thinking. This might mean that assessment activities were applied haphazardly.

We will now provide a detailed explanation of how three inferred lesson objectives were classified within the Taxonomy Table and how this resulted in the frequency shown in Table 3. The assessment activity from which the lesson objective was inferred is provided together with an extract from the curriculum specifications as supplied by the DoE (2002) to show the intended level that may have been addressed by the work covered in the lesson. The latter provides an opportunity to further calibrate both the outcome that has been inferred as well as the levels at which it has been placed in the taxonomy.

(i) **Assessment activity:** *How do you prevent rust at home?*
The inferred lesson objective, classified under Remember and Factual, is thus

At the end of the instruction learners must list ways of preventing rust.

Verb: *list* – Recalling is a subcategory of Remember as it involves the retrieving (listing) of knowledge from memory (at the end of instruction).

Noun phrase: *how to prevent rust*. This addresses the curriculum requirement for processing in Learning Outcome 2. The related assessment standard reads as follows: “demonstrate knowledge and understanding of how materials can be processed to change or improve properties” (DoE, 2002:46). Learners need to list ways to prevent rusting of materials. In this lesson one of the educator’s activity aims was to establish that corrosion resistance is when corrosion is avoided through painting or galvanisation, which requires six steps. The learner activity was to provide answers to *how do you prevent rust at home?* Learners were expected to list ways they might use to prevent rust at their homes. Initially the educator seemed to be defining corrosion resistance. However, this was not done as corrosion resistance is a property of material to resist being eaten away by chemical reactions or weather conditions, rather than how corrosion is prevented.

(ii) **Assessment activity:** *Research on increasing the lifespan of materials through varnishing and painting*.
The inferred lesson objective, classified under Analyse and Conceptual,

After the instruction learners must be able to perform research on increasing the lifespan of materials through varnishing and painting.

Verb: *perform research* – Differentiating is a subcategory of Analyse, which includes distinguishing between varnishing and painting.

Noun phrase: *increasing life-span of materials through varnishing and painting.* This addresses the curriculum requirement for processing in Learning Outcome 2. Assessment Standard 2

Table 3 Frequency of the implicitly stated (inferred) lesson objectives within the Cognitive Process dimension and the Knowledge dimension ($N = 62$)

Knowledge dimension	Cognitive process dimension						Frequency of the knowledge dimension
	Remember	Understand	Apply	Analyse	Evaluate	Create	
Factual	18	5		4	1	1	28(45%)
Conceptual	8	1		5			14(23%)
Procedural	3	2		3		2	20(32%)
Meta-cognitive							0 (0%)
Frequency of the cognitive dimension	29(47%)	8(13%)	0(0%)	12(19%)	1(2%)	12(19%)	

states: "demonstrate knowledge and understanding of how materials can be processed to change or improve properties" (DoE, 2002:46). Learners need to analyse the two concepts *varnishing* (which is done on wood) and *painting* (which can be done on both wood and metal) through research on how the lifespan of materials can be extended. The lesson content was on explaining different ways to process material in order to prevent corrosion or rust. Concepts like *galvanising* were explained to learners; hence learners were expected to research other methods such as varnishing and painting. Learners thus demonstrated Conceptual knowledge.

(iii) **Assessment activity:** Use hand-outs given and follow instructions on the hand-outs and make a toy of your choice.

Inferred lesson objective classified under: Create and Procedural
Following the instructions from the hand-outs, learners should be able to make a toy of their choice.

Verb: *make* – Constructing is a subcategory of Create which involves putting elements together to form a functional product.

Noun phrase: *a toy*. This addresses the curriculum requirement for making in Learning Outcome 1. The assessment standard relates to the making phase of the design process. Although the learners would show their creativity, the instruction did not require of learners to follow the IDMEC process (Investigate, Design, Make, Evaluate and Communicate). Learners would be required to engage in creativity by making a toy of their choice and following some procedures during the making stage. Procedural knowledge would be applicable but learners' creativity could also fall under the application of following instructions provided in the hand-outs. The high cognitive level of Create was thus compromised by the availability of detailed instructions, yet learners could have ignored some of the instructions, or could have applied them loosely, thus using the higher classification.

The last two examples seem to have required higher cognitive levels but under scrutiny also show some dominance of lower cognitive levels in the actual activities. Therefore, it seems that the teachers' intentions to teach learners at higher cognitive levels do not really happen. The lack of explicitly stated objectives in these lesson plans supports the conclusion that while activities are described in terminology derived from higher cognitive levels, the actual implementation falls short of higher levels, possibly due to teachers themselves being unclear regarding the meaning of higher levels.

Explicitly stated and inferred lesson objectives are combined in Table 4 to further show the frequency of the cognitive process and knowledge dimensions.

Table 4 is a combination of information from Tables 2 and 3. From Table 4 it is apparent that teaching and learning happens mostly at Factual knowledge (46%) and at the lowest thinking level, Remember (37%). The placement of objectives at the high cognitive level, Create, should be accepted with some caution as Create in the absence of evidence of Analyse or Evaluate is somewhat suspect. The Analyse and Evaluate levels may have been present if the IDMEC process had been required, but the need for the process is explicitly excluded in the specifications of the DoE (2002). Were one to move the classifications under the Procedural-Create classification to Procedural-Apply according to the dominant nature of the Create and Make activities, the table would have a smoother transition from lower to higher levels, with the vast majority of objectives (73%) falling at levels lower than Analyse or Evaluate (26%).

Conclusion

Krathwohl (2002) advises that the most important goal of education is to produce learners who show understanding in their learning, and this only happens when learners are exposed to activities that require them to operate within objectives framed within the higher levels of the cognitive domain, those ranging from Understand to Create.

From the findings of this study it is clear that most objectively stated teaching in Technology happens at the lower level of the cognitive domain and addresses predominantly Factual knowledge. Teaching on the higher level of the cognitive domain was found only in lessons where learners were given assessment activities without clearly stated objectives, and objectives have been inferred from specified activities. These were generally the more integrative tasks where learners were required to make artefacts or perform some investigation or research, which would allow for their analytical skills and creativity to be developed or used. However, without the requirement of following a design process, these tasks have been more the realisation of process application or recipe-like instructions.

The low level of Technology teachers' lesson objectives in terms of knowledge and cognitive level indicates that the most important goal of education, namely, to produce learners who show understanding and the ability to apply their learning, is not achieved. This is unfortunate as teaching limited to lower

Table 4 Frequency of both explicitly stated and inferred lesson objectives within the Cognitive Process and Knowledge dimensions ($N = 84$)

Knowledge dimension (Rows)	Cognitive process dimension						Frequency of the knowledge dimension
	Remember	Understand	Apply	Analyse	Evaluate	Create	
Factual	20	11		7	1		13(15%)
Conceptual	8	3		9	1		39 (46%)
Procedural	3	2	2	4		13	21 (25%)
Meta-cognitive							24 (29%)
							0 (0%)
Frequency of the cognitive dimension	31 (37%)	16 (19%)	2 (2%)	20 (24%)	2 (2%)		

cognitive levels fails to develop learners' higher-order thinking skills required for further study or independent practice in work environments. This does not bode well for the current skills shortages or for the development of a competitive economy. Teachers should be encouraged to change their practices of developing assessment activities without clearly stated lesson objectives as this affects learners' ability to appreciate the actual performance level that is required. It is possible that educating teachers in the use of the cognitive taxonomies as a reflective tool during the planning of lessons, particularly their objectives, activities and assessments, may address the apparently haphazard application of assessments, or misalignment between activities and assessments.

Further research should be undertaken to determine why teachers seem to avoid teaching with clearly stated objectives and why teachers do not present lessons to address the higher cognitive levels or meta-cognitive knowledge domains that can be addressed in Technology. If teachers have low expectations of learners they will succeed only to these low expectations (Metcalfe, 2008). If learners do not achieve at higher levels the aims and purpose of Technology education are not met, which bears the potential of dire socio-economic consequences of continued uncompetitiveness and unemployability of school leavers.

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