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CONCEPTUAL CHANGE IN LIFE SCIENCES LEARNING: THE IMPACT OF TEACHING TOOLS ON KNOWLEDGE REPRESENTATION

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ABSTRACT

This article explores the impact of tool-method combinations on conceptual changes, comparing the use of interactive whiteboards (TFM-IWBs) and traditional blackboards (TFM-TBBs). These combinations are integrated with traditional teaching methods (TFM) for educational purposes, focusing on natural science topics in Grade 9. The study analyzes specific changes in knowledge representation using qualitative approaches and a quasi-experimental design. The results show student knowledge structure variations depending on the tool-method combination used. The TFM-TBB combination primarily affects declarative knowledge, while TFM-IWB more significantly influences procedural and conditional knowledge. Hence, there is an impact of tool-method combinations on conceptual changes. This research recommends further investigating how different tool-method combinations affect learning outcomes across various subjects and educational levels.

PERUBAHAN KONSEPTUAL DALAM PEMBELAJARAN ILMU PENGETAHUAN ALAM: DAMPAK DARI PENGGUNAAN ALAT PENGAJARAN TERHADAP REPRESENTASI PENGETAHUAN

Kata Kunci:

Penilaian
Perubahan konseptual
Papan tulis interaktif
Representasi pengetahuan
Papan Tulis Tradisional

ABSTRAK

Artikel ini mengeksplorasi dampak kombinasi alat-metode terhadap perubahan konseptual, dengan membandingkan penggunaan papan tulis interaktif (TFM-IWBs) dan papan tulis hitam tradisional (TFM-TBBs). Kedua kombinasi ini diintegrasikan dengan metode pengajaran tradisional (TFM) untuk keperluan pembelajaran, dengan fokus pada topik ilmu pengetahuan alam di kelas 9. Menggunakan pendekatan kualitatif dan desain kuasi-eksperimental, studi ini menganalisis perubahan spesifik pada representasi pengetahuan. Hasil penelitian menunjukkan adanya variasi dalam struktur pengetahuan siswa, tergantung pada kombinasi alat-metode yang digunakan. Kombinasi TFM-TBB berpengaruh terutama pada pengetahuan deklaratif, sedangkan TFM-IWB lebih mempengaruhi pengetahuan prosedural dan kondisional. Dengan demikian, terdapat dampak kombinasi alat-metode terhadap perubahan konseptual. Penelitian ini merekomendasikan penelitian lebih lanjut untuk menginvestigasi pengaruh kombinasi alat-metode yang berbeda pada hasil pembelajaran di berbagai subjek dan tingkat pendidikan.

1. INTRODUCTION

The complex nature of how people learn poses some teaching methodological challenges to teachers. Although teachers use various and diverse criteria for selecting their teaching methods and/or tools for different concepts and/or topics, it is generally random. Most teachers use tools and/or methods that are readily available to them. These are seldom appropriate for effective teaching and/or meaningful learning. However, teachers who have access to or can use different tools and methods often need help to match these to their academically diverse learner cohorts and/or to the topics and concepts in their classrooms. Yet, technological advancement provides teachers with alternative mechanisms and tools to overcome some of these challenges. Many science education researchers have suggested multiple teaching methods, tools and activities for different science topics [1], [2]. Additionally, these activities should be considered suitable learning environments for a deeper understanding of the cognitive aspects of different learner cohorts [3], [4].

This study explores the changes in learners' knowledge structures when using different teaching methods and/or tools. We argue that knowledge structure changes should contribute to particular conceptual changes during learning. Undeniably, learners receive and respond to different tools and/or methods differently. The outcome of information received through a particular tool-method combination should result in a particular interpretation and conceptual change outcome. This study used two tool-method combinations with a common teaching method to teach the same content. The tools were the interactive whiteboards (IWBs) and the traditional blackboards (TBBs). The teacher-focused teaching method (TFM) was common for both tools. This was to determine the effect on knowledge structures in selected life sciences topics for the two teaching tool-method combinations.

Direct teaching families of methods (e.g., the lecture method) are generally teacher-centred and preferred by many teachers. Teachers use these methods at different levels of education and for different disciplines, including science education. The TFM approach was considered to facilitate students' learning and trace conceptual change. Teacher-focused methods are generally used in schools and at higher institutions of learning. The teacher generally controls the curriculum and uses their experience to help the learner make connections between concepts. The method also allows a distinct separation of the process of teaching and assessing [5], which suited the study's design. This allows the researchers to first teach and assess later to trace learners' conceptual change. They are also flexible for different class sizes, especially large classes [5], hence adopting the method in the study.

Various studies have been conducted on the use of learning tools, including representation tools for high-quality learning [6], the impact of using teaching aids on learning outcomes [7], [8], ethnomathematics-based teaching aids on mathematical communication skills [9], and understanding of concepts and mathematical communication aided by educational props [10]. However, no research has examined the impact of using teaching tools on knowledge representation. This study aims to determine the impact of teaching aids on knowledge representation from a conceptual change perspective in life sciences learning. Previous studies have used various teaching aids but not interactive whiteboards as in this study. Another novelty of this research is measuring the ability of contextual change and knowledge representation.

With the following two questions, we aimed to establish the changes different tools affect learners' knowledge structures: (1) what knowledge representations are associated with each of the two method-tool combinations (i.e., TFM-TBB/TFM-IWB) for different learners? The assumption with this question was that teaching tools are used to create varied learning opportunities. They potentially contribute to changing certain aspects of learners' knowledge structures and consequently induce conceptual changes. We were not certain of the types of knowledge structures they change, hence this question and part of the study's purpose. The study focuses on [11] three constructs of prior knowledge (i.e., declarative knowledge, procedural knowledge and conditional knowledge). Different tools will affect particular changes in knowledge structures differently. Thus, tools will be limited to certain knowledge structures and/or their types. (2) How different are learners' knowledge representation and/or structures between TFM-TBB and TFM-IWB at different levels of achievement and within the three prior knowledge constructs/types? As earlier indicated, different teaching tools necessarily affect knowledge structures differently. In addition, the same tools may affect the knowledge structures of the same learner's knowledge differently and/or in the same way. Thus, the change in knowledge structures will be affected differently depending on the tools used with different learners. This question aimed to identify differences in knowledge representation among different learner achievement levels for each method-tool combination.

2. METODE

This study was conducted at a South African school north of Pretoria's capital. The area is urban and a densely populated township. Townships in South Africa generally refer to apartheid-created, underdeveloped urban areas mostly for 'non-whites' [12]. The school is one of the pilot sites the education department uses to upgrade teaching through the introduction of ICT teaching resources. The study adopted a qualitative approach on the basic assumption that knowledge representation varies between different groups of learners and in different social settings.

The co-researcher in this study assessed the learning techniques of Grade 9 learners. This assessment was a precursor of the current study. That is the comparative use of method-tool combinations (i.e., TFM-IWB and TFM-TBB) and their effects on knowledge structures in life sciences teaching and learning. Figure 1 illustrates the two phases of the empirical process. That is the sampling and the testing (Figure 1) processes after using tools in direct teaching.

The population from which this study was conducted was Grade 9 learners whose curriculum included mathematics, natural sciences and English as subjects. The population (*n* = 1058) was sourced from five township schools (A, B, C, D & E). All five schools in the study (A) were taught mathematics, English, and natural sciences using a combination of TBB-direct teaching methods. The teaching and learning contexts of the schools varied as they used different instructional approaches and methods. A criterion for the selection of the sample for the experiment was to ensure that learners (a) have different experiences/exposures to IWB as a teaching tool, (b) came from a well-resourced school, i.e., a school equipped with technological gadgets for teaching purposes, and (c) their school in the township had a learner population with a fair socio-economic background/standard of living. In a study of this nature, the learner cohort should have particular characteristics and skills to suit the study's purpose [13]. In addition, learners had to have attended a Saturday enrichment programme for six full days (8 hours) on Saturdays. In other words, the sample was purposively selected.

The purposive sampling was based on the achievement of learners from the population of five schools on the three curriculum subjects (i.e., mathematics (Math), English (Eng), and natural sciences (NaS). That is learners set for the pencil and paper tests after exposure to the TBB teaching tool on the subjects indicated (see Figure 1). The TBB test used for all learners (n = 1058) was used to rate performance among schools in the three subjects. From the analysis of individual learners' achievement in the five schools for the three subjects, school C emerged as the worst-performing school (see "a"). School C's characteristics were appropriate for the study since the researchers wanted to understand the knowledge construction of learners at the lowest achievement level and how this level could be enhanced to promote learners' achievement. Thus, the school was selected for the experiment based on this performance and constituted the sample for the study with 136 learners (B). The flow diagram below (Figure 1) illustrates the empirical process steps from A to D.

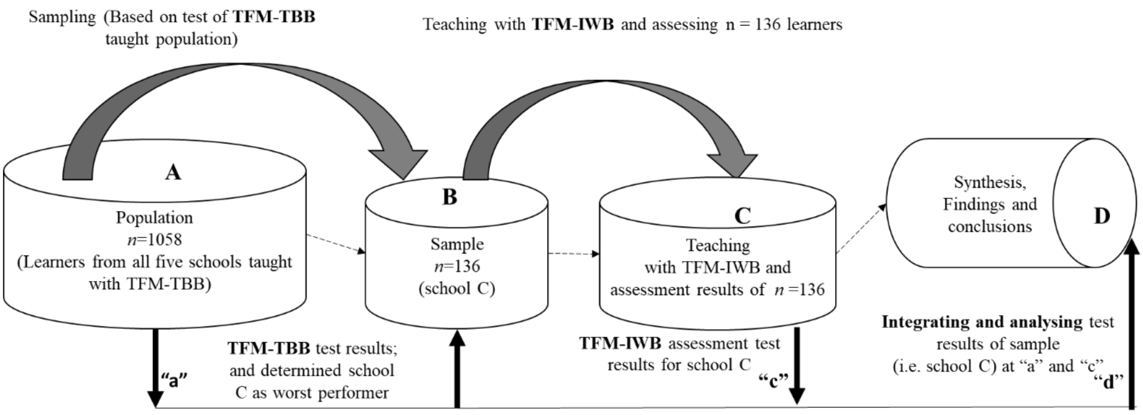

Figure 1. Sampling and the Empirical Process.

3. RESULTS AND DISCUSSION

This study mainly compared two method-tool combinations in life sciences teaching. The comparison was about their potential effects on learners' knowledge structures. Consequently, the comparison was of their representation of knowledge at different learning instances. Thus, the discussion would be on knowledge structure and the learners' representations of the knowledge emanating from these changes. The changes in one's knowledge during learning are conceptual [14]. This form of learning, they add, "…requires fundamental changes in the content and organization of existing knowledge as well as the development of new learning strategies for deliberate knowledge restructuring and the acquisition of new concepts" (p.1).

Mainly this discussion focused on two main features of the findings. First, we discuss the changes that each method-tool combination generated and their types in learners' knowledge structures. Secondly, we compared and discussed the differences in the types of changes each method-tool combination generated. As the findings were within the realm of the three constructs of prior knowledge, so were the comparisons.

Learners who went through the TFM-TBB teaching combination represented a relatively better summary of knowledge in their responses to questions. The summary description indicates a learner's ability to recall information about what was taught. This is associated directly with the method-tool combination used to produce this finding. Similarly, it is associated with teachers' and learners' familiarity with the combination. Although this study was undertaken in the 21st century, many teachers still use didactic pedagogy in their science classrooms. The CHAT explains this phenomenon as an indication of culture and the clinging to historical teaching methods because of familiarity for both teachers and learners.

On the contrary, learners struggled to represent their knowledge using informal descriptions. Informal descriptions demand learners to connect concepts for meaning construction. The TFM-TBB combination was limited as a teaching tool for this type of learning. It is teacher-focused, and learners are limited in constructing understanding on their own. This is another legacy of didactic pedagogy.

Procedural knowledge requires learners to construct understanding with the knowledge they already possess. This is the basis of constructivism, which is inherent in the CHAT. As the TFM-TBB combination is more aligned with the dated didactic pedagogy, its positive effect on logical knowledge representation is inhibited. The learner's ability to make sense of the concepts/terms through their association according to valid scientific rules is hindered by the limitations of method-tool combinations. Teacher-focused methods such as the TFM-TBB limit learners' access to reflective thinking as the teacher is dominant and/or limited in the tools to engage learners. Thus, learners do not have opportunities for reflection and/or prevent errors in their learning (Reif, 1985). The TFM-TBB combination limits constructivist teaching and/or activity learning.

Where responses to questions require recall, there cannot be much restructuring, irrespective of the method-tool combinations used in teaching. Therefore, in this case, there was little difference in the effect of TFM-IWB and TFM-TBB combinations in teaching summary descriptions of knowledge. On the contrary, there was a marked change and improvement among learners' responses using the TFM-IWB combination for questions requiring the relational linking of concepts to construct new meanings, that is, informal descriptions. Although the method was teacher-focused, there was a heightened interaction and activity. This interactivity creates more accessible paths for learners and their teachers to construct meanings and understanding. The activity aspect of the CHAT explains the purpose of interactivity well in terms of the opportunity to construct new knowledge through conceptual change.

Knowledge application is one of the important goals of constructivist learning through activity. Using the TFM-IWB provided a much-improved knowledge instantiation. This was evident when learners were more specific in using concepts and terms. They could move from the general representation of knowledge to clear and detailed interpretation and representation of concepts. In addition, learners were reflective of their knowledge. Generally, the use of the TFM-IWB combination affected many and various parts of knowledge representation differently. This was necessitated by the ability of the TFM-IWB combination to access and expose concepts and phenomena from different angles through activity as advocated by the notion of interaction in learning.

The differences in the effect of the TFM-TBB and TFM-IWB tools on knowledge structures can be explained by the learning contexts they create. Teaching methods or the tools embedded in them, irrespective of their type, cannot solely affect the same knowledge structures and/or change learners' conceptions the same way. Different teaching methods or tools create particular social and learning contexts differently. Thus, the conceptual changes can be explained mainly by the contexts of learning. Different learning environments (different designs, methods, tools, etc.) will yield different conceptions of scientific concepts [14]. These outcome differences between the tools may be better understood through Bandura's [15] notion of learner-interpersonal interaction. That is, the notion that tools have the attraction and capability to advance learners' mental coding of visual and audio. In this study, the TFM-IWB tool possesses these characteristics. The impact of such traits in the study has enhanced both procedural and conditional knowledge restructuring.

Following the above results, we have the potential to precisely predict the type of knowledge changes that are likely to be accommodated by different tools in particular contexts, especially when teachers are to teach concepts similar to that of the photosynthesis and respiration phenomena. For example, we can prescribe TFM-IWB for procedural knowledge and conditional knowledge. We can also discourage the use of TFM-TBB as a tool for the same knowledge as TFM-IWB. The study used the same assessment methods in both TFM-TBB and TFM-IWB to carefully measure the impact of the tools on learners' knowledge restructuring. Cultural and historical activity theory accounts for the culture that developed over the years through direct teaching methods. Many teachers and learners are used to direct teaching and may be affected negatively by new methods or tools of teaching, such as the use of IWBs.

Cultural and historical activity theory also accounted for the external variable that could not be controlled in the study. Learners gain insight and understanding in the manner and the nature in which the teaching method is carried out. Generally, teachers should be able to use different methods in different contexts to accommodate the majority of their learners. In addition, teachers should be able to adapt methods to their learners, the subject matter content, and the prescribed curriculum learning outcomes. In other words, both the use of the TFM-IWB and the TFM-TBB method-tool combinations should be accommodated in all teaching and learning contexts.

Table 1. Findings of Learners' Knowledge Representation

Types of Prior Knowledge Constructs	**Knowledge Structures at Different Stages of Learning**		
	TFM-TBB **Learners' Responses**	**TFM-IWB** **Learners' Responses**	**Differences Between Knowledge Representations from TFM-TBB and TFM-IWB**
Declarative knowledge Unit of analysis: Specification of concepts	TBB_{Rose} • Oxygen that all people in the world need • Carbon dioxide that plants need to survive	IWB_{Rose} • Plants give us oxygen • Carbon dioxide, water for plants • Plants give us food to eat.	• No change in knowledge structure detected from TBB to IWB • Learners gave the same summary and informal description in TBB and IWB • In responding to the question, both learners used summary descriptions
	TBB_{John} • Air to breath • Carbon dioxide	IWB_{John} • Oxygen to breathe • Food to eat • Glucose for energy.	• There is an elaboration in IWB. That is, the learner's answer is more on specific concepts • The learner possessed summary description in TBB and improved to informal description in IWB

	TBB_{Ben} • Make lots of food	IWB_{Ben} • Plants would not suffer for food	• The learner could not understand the question in the TBB but displayed a summary description and showed significant improvement in the informal description (IWB)
Procedural knowledge Unit of analysis: Formal or informal description and applicability conditions/instantiation	TBB_{Rose} • Plants and trees take out the oxygen that all people in the world need • And we people remove the carbon dioxide that plants need to survive	IWB_{Rose} • Because plants give us oxygen • And people give the plants carbon dioxide and water • And plants give us food to eat.	• The learner has improved in step-by-step procedure specifying the importance of carbon dioxide and oxygen in plants and humans with the additional knowledge of water playing a role in photosynthesis • Learner identification of knowledge exhibited the relationship of various concepts for possible single explanation in the IWB • Applicability condition of concepts is general in TBB and specific in IWB
	TBB_{John} • Because plants give us air to breathe • We give them carbon dioxide • So, if no plants exist, we will die and suffer.	IWB_{John} • Plants give us oxygen to breathe • It also gives us food to eat and glucose • Animals eat plants to survive • We get oxygen from the plants.	• The learner moved from general interpretation of knowledge (TBB) to provide the most detailed interpretation of concepts (IWB) • The application of knowledge moved from more abstract concepts (TBB) to effectively related concepts (IWB) • More concept identification in IWB than in TBB • Improved systematic representation in IWB than TBB
	TBB_{Ben} • Plants make lots of food that animals and people can eat	IWB_{Ben} • If there were no plants, humans and animals would suffer	The formal description is the same. • Improvement in informal description from IWB.

	• If no plants exist, we can never live on this earth • We must depend on plants that we can have to eat	• So, if the plants were on or had plants, they would not suffer for food	
Conditional knowledge Unit of analysis: Error prevention in knowledge use • Categorical representation of concepts • Learners' awareness of knowledge representation	TBB_{Rose} • The learner should have prevented errors in the specification rule. This happens due to the failure of the learner to specify the correct uses of photosynthesis in human life • The learner should have also prevented errors in applicability conditions. This is due to the learner's attempt to use the word world in the applicability of photosynthesis in humans • Discrimination error was successfully prevented. The learner avoided confusing the use of oxygen and carbon dioxide.	IWB_{Rose} • In the post-test, the learner continued to incorrectly state the rule or definition of concepts (error in specification rule) • The learner correctly related the applicability of the concepts to real-life situations, avoiding errors in applicability conditions	• Growth in the avoidance of error in applicability conditions.
	TBB_{John} • Discriminations in using outside language in identifying concepts, e.g., the learner used air instead of oxygen. The two are interpreted	IWB_{John} • In the post-test, the learner continued incorrectly stating the rule or definition of concepts (error in specification rule)	The learner in the IWB group showed the following knowledge in avoidance of errors: • The learners can detect any errors committed and almost correct them accurately

	differently in natural sciences • Error in applicability conditions • The learner used extended general wording specifications in cases where such words are invalid • Concepts were incorrectly stated (error in specification rule)		• The learner can use pre-existing knowledge to make judgements
	TBB_{Ben} • The learner does not possess adequate knowledge to prevent errors.	IWB_{Ben} • Despite prior knowledge, the learners still lack the knowledge to avoid likely errors, detect such errors when they have been committed, and appropriately correct them.	• No growth in error prevention.

The student-centred learning process with the guidance of a teacher is the current expectation in science education to effect conceptual change [16]. The teacher remains a facilitator of learning by asking questions and guiding learners to use effective resources to construct knowledge [17]. The study used the teacher focus method (TFM) for the teachers to effectively introduce technology (IWB) for learners to learn concepts meaningfully and implement these concepts in their lives [18]. The study then used TFM to trace knowledge construction when TBB and IWB were used. Photosynthesis and respiration were adopted as the topics of the study because of the multiple biochemical steps that occur simultaneously within plant cells. Learners often consider the definitions of these two processes without considering the relationship and the significance of the processes in the global ecosystem [19]. Photosynthesis and plant cellular respiration are considered complex dynamic processes [20], this notion allowed researchers to use the topics concerning TFM to trace learners' knowledge construction. That is, both the tools and the method used in the study have the potential to create a context that influences learners' knowledge construction.

The study's processes and findings provide researchers, teachers and science teachers in particular, a new approach to assessing learning. It also introduces assessment that may diagnose knowledge structure changes in learning particular concepts and/or phenomena. With this approach, teaching specific concepts and/or phenomena may be appropriated to particular methods or tools. This is because we can now specify the knowledge structures we want to reorganize or the conceptual change we intend to affect. However, other researchers have reported contradictory results from similar studies [21], [22]. This may be because of different contextual factors. Both studies compared the traditional teaching method and the inclusion of technological tools in the educational setting, similar to those in this study. However, the design and the approach of both studies are different.

It was argued that the variation is attributed to the study's design and the teaching environment [23]. It is, therefore, important that, as we provide the results of our studies, we also specify and document our designs for the accuracy and reliability of their outcomes. Despite the researchers having been careful with their designs and methods, inherently, there are limitations of pre-test to post-test prior knowledge interferences in this and similar studies.

4. CONCLUSION

The findings indicate variations in the knowledge structure represented by learners both within and across the combinations of methods and tools. This means that different conceptual changes were observed in knowledge representation for each tool-method combination. For example, the TFM-TBB combination most significantly affected declarative knowledge representation. The TFM-IWB combination was more pronounced in representing procedural and conditional knowledge. This study aimed to compare the use and effectiveness of two tools embedded in the same teaching approach. The objective was to illuminate the specificity of teaching method-tool combinations and their effect on knowledge structures. From the findings, we have somewhat managed to separate the effects of the two combinations. We have highlighted their effects on specific knowledge structures and associated them with particular conceptual changes when teaching photosynthesis concepts or phenomena.

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