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5E Learning Cycle Instructional Model: A Constructivist Approach in Teaching Science to Pupils with Visual Impairment

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This paper presents the 5E learning cycle instructional model as a constructivist approach in teaching pupils with visual impairment. The definition of 5E learning cycle model is defined to set the tone of the discussion. More so, the stages of 5e learning circle instructional model are outlined. The paper also highlights educational considerations in teaching science to pupils with visual impairment Inquiry based learning for pupils with visual impairment in science classrooms was presented. Constructivism in science teaching and learning was also examined. In addition, the benefits of 5e learning circle instructional model to pupils with visual impairment. Finally, a way forward was presented in terms of modification of the curriculum for pupils with visual impairment in order to accommodate learners with through the effective use of 5E learning cycle instructional model

Keywords: 5E learning cycle instructional model, science teaching and learning, visual impairment

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INTRODUCTION

Over the years, Science teaching has relied on methods that train pupils to follow directions with little connection to inquiry based teaching methods and pupils have become accustomed to this method of learning, most of which do not form a deep conceptual understanding of Basic Science and Technology (Nadelson, Williams & Turner, 2005). The most prominent among these methods is the textbook approach which is more challenging to pupils with visual impairment due to lack of vision to see diagrams and illustrations replete in textbooks. Pupils are also unable to carry out experiments, measurements and observation which are core activities in explaining and describing concepts in Basic Science and Technology lessons. The Education Development Centre (2007) asserts that 38% of pupils with visual impairment hardly receive any instruction in Science and 90% of teachers who teach Basic Science to pupils with visual impairment often employ the text-book approach in teaching.

Visual impairment is an umbrella term that is often used to describe a loss of vision that usually occurs even if the individual uses corrective lenses and can be as a result or consequence of a number of different medical/health conditions. As asserted by Erin (2003), it is one of the most prominent low incidence disabilities affecting approximately 1 in 1000 pupils globally. The nature and degree of visual impairment may vary significantly. Each student may require individual adaptations to instructional practices/experiences as well as specialized materials in order to learn effectively.

There is a decreasing popularity of science among pupils and students with visual impairment as evidenced by the declining number of these pupils opting for choosing science subjects in Nigeria (Omalase, Fadamiro, Omolase, Aina, & Omolade, 2008). The decline in number of these pupils as observed may be due to the text-book approaches adopted by teachers in teaching Basic Science and Technology to pupils with visual impairment. This approach often makes the subject appear difficult, tedious and boring. It provides little opportunity for students to assess how well they are learning the content. Pupils do not usually ask many questions because they are not able to understand some abstract and difficult Basic Science and Technology concepts including water evaporation and forms, parts and functions of the human heart, measurement of length and volume among other concepts that involve experiments, observation, description and measurements.

Pupils with visual impairment have over the years received instruction through deductive approaches. In this situation, Stofflett (1998) posits that pupils are expected to blindly accept the information they are given without questioning the instructor while they are not always engaged in activities that will promote learning. The various categories of pupils with visual impairment (low vision and total blindness) should be taught with instructional strategies that will suit their unique learning needs. Pupils with visual impairment in Nigerian primary schools (inclusive or special) often need accommodations in order to effectively and fully access the curriculum.

Consequently, there is a total dissatisfaction on how science is still traditionally being taught to pupils with visual impairment (Yaksat & Hill, 1994). This dissatisfaction and its inherent challenges have led to a major shift towards inquiry-based practices in the teaching and learning of Basic Science and Technology. This major shift towards inquiry-based approaches in science has led to the development of the 5E instructional model. However, literature is replete with the 'E' learning circle models such as 3E, 4E, 5E, 6E, and 7E. This study is hinged on the 5E instructional model. The 5E model is an example of a structured inquiry learning circle approach developed in the mid 1980's by principal investigator Roger Bybee and his team members: Joseph Taylor, April Gardner, Pamela Scotter, Janet Powell, Anne Westbrook, and Nancy Landes. It was developed specifically for Science programmes and it is used in the Biological Science Curriculum Study (BSCS). The model is aimed at transforming the teaching and learning of science that is based on most recent research, ensures scientific accuracy, includes field test with diverse pupils (including pupils with visual impairment) in diverse settings and upholds the principle of universal design for learning amongst others (Bybee et al. 2006).

The American Council of the Blind (2015) maintains that pupils with visual impairment typically learn inductively (progressing from local, specialized knowledge to more general conceptual knowledge) in addition to providing adequate descriptions that can help them master the concepts underpinning the deductive learning. Therefore, they require inductive instructional approaches that will give them the opportunity to explore using the senses they often rely on due to lack of sight (hearing, tactile/kinesthetic, olfactory).

THE 5E LEARNING CIRCLE INSRUCTIONAL MODEL

The learning circle model is an instructional model based on the constructivist approach. It was first developed by Robert Karplus and the learning circle involved three consecutive phases known as the exploration, concept introduction and concept application. The learning circle has been embraced in science teacher education as a suitable approach that is consistent with the goals of the National Science Education Standards (Rubba, 1992).

According to Opara and Waswa (2013), the learning circle is a model which builds on students' prior knowledge but also shifts emphasis from the instructor to the learner and the active role played by the learner in the learning process. The learning circle approach which has been extensively used since its origin in the 1960s has been revealed by several research studies that it can result in greater achievement in science, better retention of concepts, improved attitudes towards science and science learning, improved reasoning ability and superior process skills than would be the case with the traditional instructional approaches (McComas III, 1992).

The 5E Learning Circle Model is further presented in this diagram: (Figure 1)

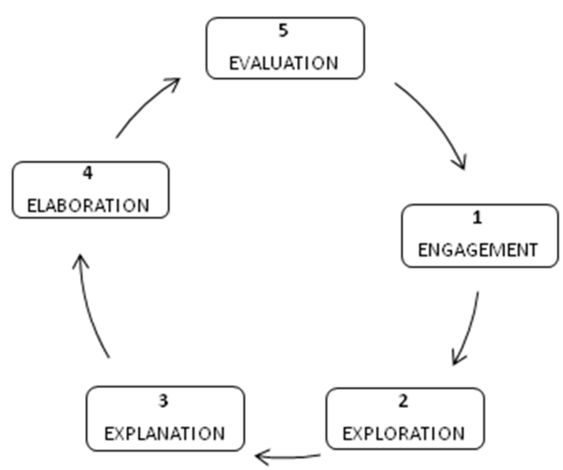

Figure 1: The 5E Learning Circle Instructional Model.
Source: Latrobe University (n.d)

The diagram on above presents a representation of the 5E starting with and cumulating with the evaluation stage. However, each stage has a specific function and contributes to the coherent instruction of the teacher as well as to students' formulation of a better understanding of scientific and technological knowledge, attitudes and skills. Each stage is an essential component of the 5E Learning Circle Model. The 5E Instructional Model as the name implies, constitutes five discrete elements such as: Engagement; Exploration; Explanation; Elaboration and Evaluation. Each phase of the model, according to the Biological Science Curriculum Study (BSCS, 2015) indicates its purpose from both teachers and pupils' perspectives to include: engagement (pupils prior knowledge accessed and interest engaged in the phenomenon); exploration (pupils participate in an activity that facilitates conceptual change); explanation (pupils generate an explanation of the phenomenon); elaboration (pupils understanding of the phenomenon is challenged and deepened through new experiences) and evaluation (pupils assess their understanding of the phenomenon). The exploration phase is very important for pupils with visual impairment as it gives them the opportunity to explore (examine) real objects or models of objects tactually while the elaboration phase gives them the opportunity to clear doubts or misconceptions that may arise after the exploration phase. The 5E instructional model helps to develop pupils' critical thinking skills, ensures adaptability, encourage complex communication, self-development and teamwork. As opined by Balci, Cakiroglu and Tekkaya (2006), once students become aware of their own reasoning and apply new knowledge successfully, they are more effective in searching for new patterns

STAGES OF 5E LEARNING CIRCLE INSTRUCTIONAL MODEL

The 5E learning model sequences learning experiences so that students have the opportunity to construct their understanding of a concept over time. The model leads students through five phases/stages of learning that are easily described using words that begin with letter E: thus: E-Engage, E- Explore, E-Explain, E-Elaborate and E- Evaluate. The 5Es according to Abraham (1998) involves a learning circle approach that incorporates scientific inquiry and modeling. Each of the 5Es is implemented thus: a) engagement (to access prior knowledge and purposeful create connections between past and present learning experiences); b) exploration (to allow students to generate new ideas and explore questions, design and conduct investigations); c) explanation (to make sense of a phenomena); d) elaboration (to use new experiences to challenge, apply and develop understanding and infused throughout the model) and e) evaluation (to use assessment throughout the entire learning process.

According to Ansberry and Morgan (2007), the 5E learning circle model provides a planned sequence of instruction that places students at the center of their learning experiences, encouraging them to explore, construct their own understanding of scientific concepts and relate those understandings to other concepts. The stages/phases of 5E learning circle model are further described below:

Engagement phase (E1): Teachers accessed pupils' prior knowledge and helped them become engaged in a new concept through the use of short activities that generated enthusiasm and accessed prior knowledge. The activities helped to make connections between what pupils with visual impairment know and can do, expose prior conceptions, and organize pupils' thinking toward the learning outcomes of the current topic.

Exploration phase (E2): Exploratory experiences provided pupils with visual impairment with a common set of experiences within which present concepts (i.e., misconceptions), processes, and skills were reflected and conceptual change was facilitated. Pupils with visual impairment had the opportunity feel and touch objects (real life and models) in order to have clearer understanding of concepts introduced in a lesson and pupils compared ideas that identified inadequacies of current concepts. Learners were not just passive receptors, they also had chances to acquire knowledge actively. They were given opportunities to manipulate materials using existing knowledge to generate new ideas, explore questions and possibilities, and execute preliminary investigations.

Explanation phase (E3): In this phase, there was more interaction between teachers and pupils with visual impairment. The explanation phase focused pupils' attention on a specific aspect of their engagement and exploration experiences and provided opportunities for pupils to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provided opportunities for teachers to use direct instruction. Pupils with visual impairment also explained their understanding of the concept. An explanation from the teacher or the curriculum was provided to serve as a guide them to modify and enhance their conceptual understanding.

Elaboration phase (E4): Teachers challenged and extended students' conceptual understanding and skills at this phase. Through the new experiences, pupils learned to develop broader and deeper understanding and adequate skills, and perhaps acquired additional information.

Evaluation phase (E5): The evaluation phase encouraged pupils with visual impairment to assess their understanding and abilities and provided opportunities for teachers to evaluate pupils' progress toward achieving the learning goals.

EDUCATIONAL CONSIDERATIONS IN TEACHING SCIENCE TO PUPILS WITH VISUAL IMPAIRMENT

Teachers of pupils with visual impairment often find it challenging to explain certain concepts to pupils with visual impairment especially abstract concepts. These pupils miss out of teaching and learning experiences due to lack of vision as it is believed that 80% of what pupils learn is through visual cues; the other senses do not fully compensate for the loss of sight. Therefore, touch and hearing are substitutes/alternative senses that pupils with visual impairment often rely on to learning (Project IDEAL, 2013). They require compensatory skills and adaptive techniques in order to be also to acquire knowledge through other methods than the use of sight. This is due to the fact that they cannot learn effectively through visual cues rather; they can benefit maximally from instructions through verbal and tactile cues. Dion, Hoffman and Matter (2000), added that sighted persons create abstract concepts by putting many characteristics in a group. These abstract concepts can be used to classify and understand objects. However, this is not applicable to individuals with visual impairment who has concrete concept of the world. The objects that are tactually explored and identified will have meaning but a picture of the same object will be difficult to identify.

According to Riley (2000), adaptation to vision loss is shaped by many factors such as availability and type of family support and also degree of intellectual emotional, physical and motor functioning. In addition to the nature and extent of vision loss, a variety of factors needs to be considered in designing an appropriate educational programme for a child who in be totally blind or having low vision. These factors may also change over time based as the pupils with visual impairment progresses. As opined by Curry and Hartlen (2007), pupils with visual impairment deserve the same instruction in reading, mathematics, social studies; language arts etc. that their seeing peers receive. Therefore, pupils with visual impairment deserve chronological age and developmentally appropriate instruction in the skill areas required to meet their needs as pupils with visual impairment. The first step in providing educational programmes for pupils with visual impairment is to know their status in order to categories them accordingly. Pupils with visual impairment can be assessed through expert diagnostic screening procedures involving such test as visual acuity test, colour test, visual field test and ocular mobility tests (Arthur & Lan, 2001). Visual acuity assessment is inevitable in educational school setting because and it can easily be carried out and teachers of pupils with visual impairment as well as general classroom teachers can easily administer it as well as derive meaning from it. In addition, it will enable teachers and administrators to provide adequate materials for instruction and placement options that will meet the unique educational needs of pupils with visual impairment in schools.

Programme considerations for pupils with visual impairment should be based on sound practices including the use of concrete (not abstract) teaching methods and also stressing the relationship among objects in the environment. Students with visual impairment need instruction in braille large print, auditory or other alternate formatted materials computer and other assistive technologies etc. In line with the above assertion, Project IDEAL (2013) maintains that individualized instruction should be provided for pupils with visual impairment as well as adaptation of classrooms to accommodate them, provision of materials in the appropriate media (braille, recorded media), computer adaptations through the use of assistive media etc.

INQUIRY BASED LEARNING FOR PUPILS WITH VISUAL IMPAIMENT IN SCIENCE CLASSROOMS

Science education is aimed at developing cognitive skills while engaging pupils in different scientific activities. According to Shaheen, Alam, Mushtaq & Bukhar, (2015), some of these cognitive skills include adaptability, communication/social skills, non-routine problem solving and self-management/self-development and system thinking. In order to develop these cognitive skills, teachers need to be very careful while choosing instructional models that will be suitable for different categories of learners. Students with visual impairment irrespective of their visual loss have the right to acquire scientific skills that will enable them to explore and understand the world around them. Teaching these skills to pupils with visual impairments usually pose a serious challenge to teachers as well as parents.

Willings (2014) asserts that a student who is blind or visually impaired will typically need some accommodations in order to safely and fully access the science curriculum. It is important to meet with the teacher of pupils with visual impairments to discuss the curriculum, objectives and content that will be covered during the school year. Pupils' unique visual needs should be taken into consideration when determining learning materials and instructional pedagogies. These science materials may include measuring devices, charts, reading materials and equipment. Dion, Hoffman and Matter (2000) asserted that pupils with visual impairment tend to conceptualize concretely. Since the concepts based on visual information, a pupils' ability to form these concepts depends on their amount or residual vision. Pupils often rely on tactual and audible materials for learning. Conversely, tactual and audible methods can be time consuming and limited. While exploring or learning about something tactually, the pupil must be able to explore all parts of the object and also when learning audibly, a pupil must have an accurate description to obtain a clear understanding.

As a child with visual impairment attends school, he/she is likely to be excluded from various practical aspects of Basic science and technology as well as mathematics thus receiving an education that is far from being adequate in preparation for life in an increasingly scientifically and technologically oriented country such as Nigeria (Hill & Jurmang, 1996)

In the same vein, Crawford (2000) maintains that inquiry learning is an action-based approach to learning that "supports teachers to facilitate students reconstructing their own knowledge through a process of interacting with objects in the environment and engaging in higher thinking and problem solving. Inquiry provides students the opportunity to ask thought provoking questions not normally posed in a general science classroom (Scott, 1994; Rop, 2003). This is particularly beneficial to students with visual impairment who do have the opportunity to access visual information and rather depends on tactile and verbal instructions. They ask questions based on what they touch, feel and/or hear the teacher or their peers emphasize. The greatest evidence of the power of inquiry in the classroom is that students feel empowered of being able to make their own choices (Marrero, 2000).

As revealed by Smith (2013), there has been little change in pupils engaging in active exploration of phenomena, ideas and relevant Science questions or the use of open investigations. This is apparent when pupils involved have impaired vision and teachers tend to justify the non-involvement of pupils in Science lessons which are mostly experimental in nature due to their lack of sight and have little or nothing to benefit from such learning instruction. Teachers of pupils with visual impairment are not aware of the appropriate inquiry-based teaching/learning strategies they can adopt in teaching Basic Science to pupils with visual impairment at the elementary school level. This statement is ascertained in various studies and reports on elementary science education which identified three major challenges of elementary science teachers to include: (1) limited pedagogical science subject matter knowledge;(2) their limited science subject matter knowledge; (3) low confidence and self-efficacy with science content and science teaching (Tosun, 2000; Lee & Houseal, 2003; Cone, 2009; Appleton, 2007; Minger & Simpson, 2006,). These challenges are more evident when pupils involved have visual impairment and cannot benefit maximally from visual materials in science classrooms.

Zaborowski as cited in Wild and Allen (2009) maintains that there is paucity of research-based science education practices for students with visual impairment and therefore the need for a more research- based accommodation for this category of pupils is inevitable. More so, Ajaja and Urhievwejire (2013) asserts that literature on science education methods in Nigeria indicates that studies on learning circle models are scanty and unavailable. According to the authors, this implies that there is a general poor knowledge of learning circle procedure and its effectiveness in instructional delivery among science educators, researchers and science teachers.

As observed by the National Research Council (NRC, 1996), the American Association for the Advancement of Science, (AAAS, 1993) and the National Science Education Standards (NSES, 1996) as well as the Benchmarks in Science Education advocated the creation of inclusive science education, which encompasses all students regardless of race, nationality and cultural background. Therefore, all children (with or without a special need) including children with visual impairment should be given the opportunity to acquire scientific skills. As Science opportunities for children with special educational needs are often restrictive and sometimes non-existent. Learning science through the inquiry method promises to improve students understanding, participation and enjoyment in relation to scientific activities and contributes to improving general education (Harlen & Allende, 2006).

According to Rooks-Ellis (2014), a child with visual impairment cannot develop concepts when relevant experiences are deficient. If a child's concept is deficient, then the child's learning and understanding of world meanings also will not develop. Science instructional practices focused on scientific inquiry and modeling can help learners develop deep understanding of subject matter and to develop science process skills (Lehrer & Schauble, 2000; Schwarz & White, 2005). This is due to the fact that pupils build new knowledge and understanding to learn science as this according to Brandsford, Brown & Cocking (2000), is based on a) what they already know and believe b) modifying and refining their current concepts and c) by adding new concepts to what they already know. This implies that effective learning of science concepts requires that students take control of their own learning.

CONSTRUCTIVSM IN SCIENCE TEACHING AND LEARNING

Constructivism is divided into three broad categories: cognitive constructivism, social constructivism and radical constructivism. However, this study is hinged on the cognitive constructivism because the philosophy of inquiry-based learning finds its antecedents in constructivist learning theories. Generating information and making meaning of it is based on personal or societal experience which is also referred to as constructivism (Glassersfeld, 1995; Bachtold, 2013). The learning Circle Model is based on Piagets theory of cognitive learning and the cognitive constructivism theory is also referred to as trivial constructivism (Bevevino, Dengel & Adams, 1999).

Inquiry is congruent with constructivist teaching ideology (Adams, & Hamm, 1998; Llewellyn, 2002; Etheredge & Rudnifsky, 2003) which emphasizes students' prior knowledge as the foundation of further learning. This implies that previous knowledge of students is relevant especially to pupils with visual impairment in building new knowledge and promoting active learning. Constructivism has its origins in Vygotsky's (1978) work on child development and education. The key to this teaching strategy is having students get involved in any learning activity. Rhinehart (2012) maintains that the constructivist learning theory operates on the principle that students build knowledge based on prior knowledge. Constructivism theory avoids direct instruction. Instead the teacher guides students in discovering knowledge on their own. According to Fletcher, Meyer, Barufald, Lee, Tinoca and Bohman (2004), constructivist pedagogies that consider scientific literacy to best foster science literacy for all students is recommended. Pupils with visual impairment require a constructivist approach which promotes conceptual change, exploring of the environment and enables them become aware of their own reasoning and apply new knowledge successfully. As revealed by Landau (1993) a pupil with visual impairment cannot develop concepts when relevant experience is deficient due to their lack of vision. The child's learning and understanding of word meanings will also not develop due to his/her vision loss. Therefore, a pupil with visual impairment requires an inquiry based instructional strategy such as the 5E learning circle inquiry model in order to easily understand concepts most especially, Basic Science and Technology.

According to National Institute of Health (NIH, 2010), the guidelines for lesson planning maintains that students are active thinkers who construct their own understanding from interactions with phenomena, the environment and other individuals is based on the theory of constructivism. A constructivist view of learning recognizes that students need time to: a) express their current thinking; b) interact with objects organisms, substances and equipment to develop a range of experiences on which to base their thinking; c) reflect on their thinking by comparing what others think; and d) make connections between their learning experiences and the real world

As postulated by the Science Academic Content Standards (2005), the essential features of constructivist learning is: (a) learning is active (b) learning is interaction of ideas and processes (c) new knowledge is built on prior knowledge learning is enhanced when situation in contexts that students find familiar and meaningful (d) complex problems that have multiplied solutions enhance learning (e) learning is augmented when students engage in discussion of the ideas and processes involved. This implies that teachers often sets up problems and monitors students' exploration, guides students inquiry and also promotes new patterns of thinking for students based on prior knowledge. According to Fittel, (2010), a key element of constructivist pedagogies is recognizing the role of prior knowledge in learning. Therefore, learning takes place by evaluating the prior knowledge of the learners and introducing a new concept based on the already existing knowledge.

BENEFITS OF 5E LEARNING CIRCLE INSTRUCTIONAL MODEL TO PUPILS WITH VISUAL IMPAIRMENT

There have been debates over the merits and limitations of inquiry and direct approaches to teaching science with strong opinion on both sides. The direct side is leading in recent years with the formulation of the national and state education science education standards where inquiry has become the *sine qua non* for science instruction for all categories of learners including pupils with visual impairment (Albert, 2008). Science should not be about regurgitating definitions and facts told by a teacher. It should entail detailed explanations and exploration to describe difficult concepts to learners. Gago, (2006) posits that it should be about pupils collecting information and definitions and using them to draw conclusions of their own and through their own analysis, questioning and data collection.

The 5E model of instruction has had a positive impact on student learning because it has been proven to motivate students with the fun activities that are often involved in lessons (Boddy, Watson & Aubusson, 2003). In the same vein, 5E model allows students to gain scientific knowledge taught to them based on prior experiences and allows them to go through a series of steps to construct new knowledge based on what is in their existing knowledge. According to the Bright Hub Education (2012), the advantages of an inquiry based learning includes the following: a) students using an inquiry based learning approach take responsibility for their learning tasks; b) students are actively involved in the planning and preparation phase and develop skills in these areas and c) teachers are able to develop "softer skills" in their students such as cooperation, teamwork, planning and organization and creativity, all of which are vital and are often the focus of many and varies special education teaching strategies used throughout the curriculum.

The 5E learning circle model helps to develop students' critical skills to help them adapt better to the demands of the 21st century. This includes adaptability, complex communication or social skills, non-routine problem solving, self-management or self-development and systematic thinking. Previous woks on the use of 5E instructional application in teaching various subjects have found that this is more effective compared with traditional methods in developing conceptual understanding among students (Akar, 2005; Hanuscin & Lee, 2008; Yalcin & Ayrakceken, 2010).

A WAY FORWARD

Based on the above discussion, it is recommended that schools (special and inclusive) should adapt the use of 5E Instructional Model in the teaching of science related subjects. This is because teaching science involves experiments, exploration, observations, measurement etc. which involves the use of sight. Therefore, there is need to adapt a teaching model that will enable pupils' benefit maximally in Science classrooms. Teachers of pupils with visual impairment should give pupils with visual impairment the opportunity to explore their environment in order to actively participate in science classrooms. Therefore, the use of 5E Instructional Model takes pupils through the five stages of learning (engage, explain, explore, elaborate and evaluate) should be adopted and implemented. More so, teachers of pupils as well as students with visual impairment should be effectively trained on the knowledge, use and procedure of the 5E Instructional Model for effective use in Science classrooms at all levels of education (elementary to tertiary).

CONCLUSION

Due to the fact that pupils with visual impairment benefit little or nothing from a text-book approach, especially when they are taught difficult science concepts due to their lack of sight, there is need therefore to provide them with learning experiences that will compensate for the loss of sight as well as meeting their unique learning needs in science classrooms. More so, effective planning, reorganization and modification the curriculum for pupils with visual impairment is necessary in order to accommodate learners with visual impairment. This will encourage flexibility in the adoption 5E Instructional Models in providing meaningful learning experiences in teaching Basic Science and Technology in classrooms.

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