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Indigenous Knowledge and Nature of Science Interface: Content Considerations for Science, Technology, Engineering, and Mathematics Education

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Abstract**—**Many African countries, such as Zimbabwe and South Africa, have curricula reform agendas that include incorporation of Indigenous Knowledge and Nature of Science (NOS) into school Science, Technology, Engineering and Mathematics (STEM) education. It is argued that at high school level, STEM learning, which incorporates understandings of indigenization science and NOS, has the potential to provide a strong foundation for a culturally embedded scientific knowledge essential for their advancement in Science and Technology. Globally, investment in STEM education is recognized as essential for economic development. For this reason, developing countries such as Zimbabwe and South Africa have been investing into training specialized teachers in natural sciences and technology. However, in many cases this training has been detached from the cultural realities and contexts of indigenous learners. For this reason, the STEM curricula reform has provided implementation challenges to teachers. An issue of major concern is the teachers' pedagogical content knowledge (PCK), which is essential for effective implementation of these STEM curricula. Well-developed Teacher PCK include an understanding of both the nature of indigenous knowledge (NOIK) and of NOS. This paper reports the results of a study that investigated the development of 3 South African and 3 Zimbabwean in-service teachers' abilities to integrate NOS and NOIK as part of their PCK. A participatory action research design was utilized. The main focus was on capturing, determining and developing teachers STEM knowledge for integrating NOIK and NOS in science classrooms. Their use of indigenous games was used to determine how their subject knowledge for STEM and pedagogical abilities could be developed. Qualitative data were gathered through the use dialogues between the researchers and the in-service teachers, as well as interviewing the participating teachers. Analysis of the data provides a methodological window through which in-service teachers' PCK can be STEMITIZED and their abilities to integrate NOS and NOIK developed. Implications are raised for developing teachers' STEM education in universities and teacher training colleges.

Keywords**—**Indigenous knowledge, nature of science, pedagogical content knowledge, STEM education.

I. Introduction

GLOBALLY, it is accepted that economic development can be driven through investment in STEM [1]. As a result, STEM curricula reform initiatives have been undertaken in many African countries including South Africa and Zimbabwe. In both South Africa and Zimbabwe, teachers are expected to integrate STEM education and Indigenous Knowledge when teaching [2], [3]. It is argued that culturally embedded scientific knowledge is essential for advancing Science and Technology, which in turn can lead to socio-economic development and growth. There is a strong conviction that STEM education and the integration of indigenous knowledge in science curricula provide a potential to lay a strong foundation for a culturally embedded scientific knowledge base. The indigenization of STEM teaching and learning necessitates the incorporation of the cultural backgrounds of the indigenous learners.

The envisaged economic benefits from STEM curricula have driven these two Southern African countries into investing heavily in STEM related subject's teacher training programs. However, teacher training programs have been based on western paradigms. Essentially, they are subject-specific, non-NOS integrative and divorced from the cultural context of indigenous learners. This is in spite of the literature suggesting that the learning of both NOIK and NOS are important integrals for understanding science [4]-[6]. Their inclusion in classroom sciences has potential to ease natural sciences learning challenges experienced by learners with indigenous cultural backgrounds. The challenges accompanying non-integrative teaching have been linked to learners' demotivation in the learning of the sciences and the historic decline in science enrolments. There is an argument that the continuation of traditional science classroom practices perpetuates the decline in enrollment in STEM subjects. The consequences include continued threatening of achievement of the goals of STEM education and the aspired socio-economic gains, which can be derived from investment in STEM education in African countries.

STEM and indigenizing classroom science practices has the potential of promoting the global goals of STEM education in Africa. Expectedly, these curricula reform agenda challenge teachers. Thus, is because the PCK teachers currently hold does not support the effective implementation of these reforms. For this reason, in-service teacher professional development programs targeting scaffolding teachers' developing PCK specific to STEM teaching and integration of NOIK and NOS in science classrooms should be encouraged.

This, study therefore, provides a useful insight into an effective way of developing teachers' PCK specific to STEM, NOIK and NOS. Suffice to mention that the pedagogical approach reported here is novel and introduces a new paradigm and discourse in science education. It is argued that such a paradigm shift in science education is essential if African countries hope to achieve the envisaged goals of

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STEM education.

Accordingly, the present study sought to address the following research questions: What STEM related subject content can be drawn from the NOIK and NOS interface? (b) How can indigenous games be used to integrate NOIK and NOS content in the teaching of a STEM related subject?

II. Theoretical Framework

In this section, the three theoretical frameworks fused to guide the present study are briefly explicated. These are: the multidimensionality of knowledge; the natures of NOIK and NOS; and PCK.

A. Multidimensionality of Knowledge

This study adopted what is called the Enterprise, Paradigm, Process and Product (E3P) model to understand both NOIK and NOS. According to the E3P model knowledge production is an enterprise activity whose processes are paradigm guided. The model depicts a paradigm as embodying; interacting ontological (reality), epistemological (knowledge), methodological (processes), axiological (values) and rhetorical (lingual) beliefs [5].

B. NOIK and NOS

Two major descriptions existent in the literature on NOIK and NOS are: the dichotomous view and complementary view. The former perspective frames NOIK and NOS as mutually incommensurable [7] irreconcilable [8] incommensurate [9]. It is derived from the understanding that NOIK and NOS are based on contrasting and mutually exclusive knowledge systems, and consequently contrasting paradigmatic approaches to the understanding of the world [10]. In contrast, the complementary view, which is of interest to the present study, is of the notion that NOIK and NOS can be commensurable, with areas of interface as shown in Fig. 1.

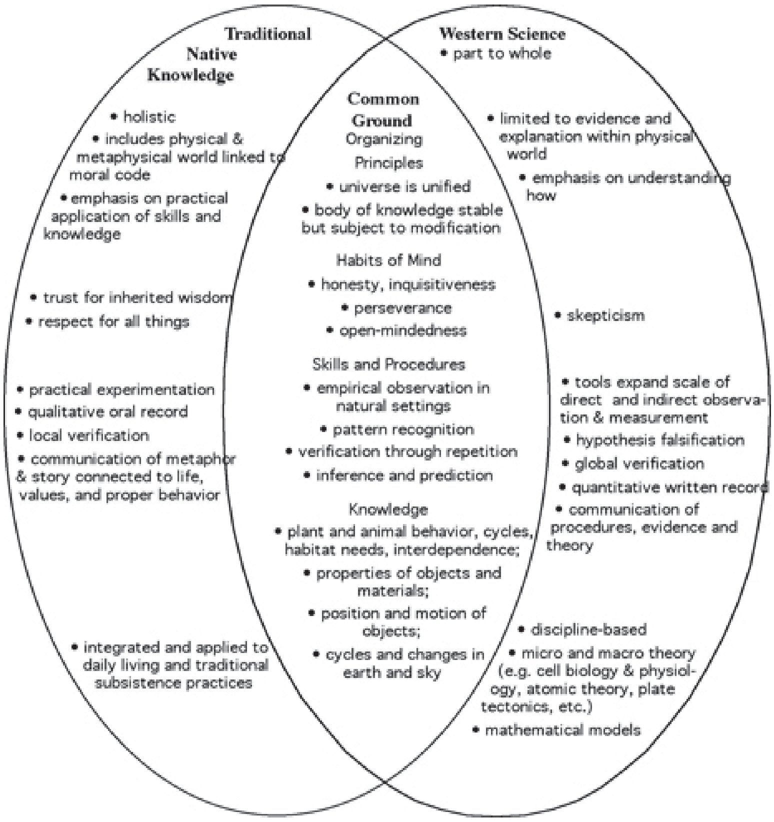

Fig. 1 The knowledge synthesis model [11, p. 16]

This complementary approach not only recognizes differences and similarities between NOIK and NOS, but also acknowledges their derivation from different cultural contexts- the Western and the African. Traditionally, NOIK emanates from the landscape of natures of indigenous knowledge (IK) and indigenous knowledge systems (IKS), whose meanings can be teased out of the literature. Indigenous knowledge interpretations of the world are grounded in a complex cultural matrix [5], [12], [13]. However, it needs be realized that IK and IKS form a cultural matrix that embraces the science, technology, religion, language, philosophy, and politics which are geographically located and can be ascribed to localized socio-cultural economies [14]. Just as Western Science incorporates STEM related disciplines such as agriculture, architecture, engineering, and chemistry [15], so does IK and IKS. It needs be accepted that, IK and IKS also incorporate

STEM related disciplines. In Western Science, NOS refers a scientific way of knowing [4]. In IK and IKS, NOIK is also a way of knowing. It is in this regard that there is commensurability. Unfortunately, NOS as derived from Western Science has been described as an epistemology or way of science knowing and IK and IKS as a primitive way of knowing. The fundamental idea that both are legitimate ways of understanding STEM has often been undervalued. The important contributions of IK and IKS to STEM have often been relegated to the dustbin of epistemology. The argument proffered here, in line with the view of commensurability is that, at the interface of these two systems can be found a common ground for developing teachers' PCK specific to STEM. The western science statements in Fig, 1 refer to the NOS. In Western science education understanding NOS has been argued as necessary in helping individuals to appreciate science as a part of contemporary culture, comprehend it and establish its links to socio-scientific issues [16]. Our paradigm of commensurability suggests that IK and IKS can equally contribute to achievement of the same values, hence the interface.

In our E3P model**,** the common grounds where interfacing occurs form the basis of teasing out commonalities in NOIK and NOS. These commonalities are shown in four categories (Fig. 1). The potential development of PCK for STEM, NIOK and NOS integration was informed by a framework developed from aligning the common categories of the synthesis model to the dimensions of the E3P model shown in Table I.

TABLE I
SYNTHESIS AND E3P MODEL MATRIX

Synthesis model categories	E3P model dimensions
Organizing principles	Paradigm
Habits of the mind	Enterprise values
Skills and procedures	Process
Knowledge	Product

C. *STEM and STEM Education*

The four distinct fields of science, technology, engineering, and mathematics are abbreviated STEM. School and college science curricula are a content, activities and pedagogy selection of scientific fields. The link between STEM and STEM education provides two main pedagogical frames in science classrooms: the traditional and integrating. Traditional pedagogy promotes independent and disconnected teaching and learning of STEM subjects in schools and colleges. Moreover, it encourages teaching that is disconnected from the cultural contexts of the learners and the real world of scientific practice and living. Such pedagogical practices largely discourage the advancement of science, technology and economic development.

On the other hand, integrating pedagogy [17], [18] advocates interdisciplinary approach to the teaching and learning of STEM related subjects. An integrated pedagogy combines teaching and learning of two or more of the STEM subject areas as well as non-science subjects offered in schools [17]. It recognizes that learners regardless of age learners "acquire knowledge through observing, listening, reading, talking, and writing about science, mathematics, history, the social sciences, and other aspects of intellectual, social, and cultural heritage" [18, p. 877] which cannot be found in one subject but exist across subjects.

D. *Pedagogical Content knowledge (PCK)*

PCK [19] is a fundamental component of the knowledge base for teaching which has been widely accepted since its introduction. PCK is what makes teachers transform the subject content or subject matter knowledge into formats which are meaningful to and can be understood by learners. It is an amalgamation of subject content knowledge, knowledge of learners, the curriculum and resources as well as teachers' beliefs about what counts as good teaching [20]. PCK development, thus capacitates a teacher so as to be able to reorganize, partition and explicate subject matter with activities and illustrations in ways that promote learners' understanding [19]. Teacher understanding of content knowledge is a prerequisite in the development of a teacher's PCK [20]. To date are several PCK models [21] that inform studies in the area of NOS research. Basically, these models concur that teacher knowledge of subject matter, including NOS and pedagogy is an essential component of PCK.

III. METHODOLOGY

A. *School Curricula Contexts*

The participants in this study were 3 South African and 3 Zimbabwean in-service teachers studying at universities in South Africa and Zimbabwe. In order to understand the study context, it is important that the curriculum frameworks guiding classroom practices in the two countries be briefly described.

1.South Africa's Curriculum and Assessment Policy Statement, (CAPS) Document

In South African CAPS documents provide guidelines for the teaching and learning of mathematics, technology, natural, physical, life and sciences subjects related to STEM in high schools [2]. These policy documents advocate for four categories of teaching and learning: knowledge, process, NOIK, and NOS. However, unlike Zimbabwe, STEM teaching and learning is made implicit rather than explicit.

2.Zimbabwean Curriculum Context

In Zimbabwe, various policy documents guide the teaching and learning of STEM related subjects in primary and secondary schools. These subjects fall into three main categories: mathematics, science and technical-vocational. The recognized science subjects include general science, geography, chemistry, physics, physical science, and biology. The technical-vocational subjects are; computer science, food and nutrition or food science, fashion and fabrics or textile designs, agriculture, woodwork, building, art, technical graphics and metal work. Offering these subjects is based on the Zimbabwe Curriculum Blueprint 2015-2022, which explicitly emphasize stemitizing classroom science [22]. This curriculum blueprint advocates for the integration of STEM subjects with studies in Arts and heritage. The indigenization of the school science is an important curriculum agenda [3].

B. Participatory Action Research (PAR)

This study adopted a PAR qualitative research approach. PAR stresses total participation of professional practitioners. This means being a participant as well as a researcher. As noted the participants were 3 South Africa and 3 Zimbabwean in-service teachers (n=6). The participants were conveniently sampled to participate in this study. The convenient sample was based on participants meeting pre-determined criteria, so called criterion sampling [23]. The criteria used were: being enrolled in the in-service science teacher program in 2016 to 2017 at either a South African or Zimbabwean University; cultural background, a clear and sincere commitment to learning more about NOS, NOIK and STEM education; and an interest to sincerely implement curriculum policy documents. Table II summarizes characteristics of the participants.

TABLE II
PARTICIPATING TEACHERS' ATTRIBUTES

Teacher	Gender	Tribe	Subject	Teaching Experience
Tadi	Female	Shona	Biology	15
Tindo	Female	Shona	Physics and Mathematics	7
Kuda	Male	Shona	Chemistry	10
Musa	Female	Sesotho	Physical science	5
Lerato	Female	Zulu	Life sciences	5
Neo	Male	Xhosa	Physical science	11

Pseudonyms have been adopted for ethical reasons.

C. Data Collection

Data collection was through semi-structured interviews and dialogues. Semi-structured interviews focused on establishing the in-service teachers' knowledge of NOIK, NOS, and STEM education as well as established indigenous games. Interviews were audiotaped. On the average, each of the six interviewees was interviewed for 90 minutes. The interviews were conducted by the first author. Each of the two groups of participants, that is, 3 South Africa and 3 Zimbabwean in-service teachers participated in integrated talk and written Task Based Dialogues (TBD). The dialogues aimed at developing the in-service teachers' PCK of NOIK, NOS, and STEM integration through the use of an indigenous game. Two video-recorded dialogues per group lasting an average 120 minutes per session were conducted. Data from interviews and dialogues were transcribed verbatim. In line with PAR, each participating in–service teacher transcribed his or her audio and video recordings.

D. Qualitative Data Analysis

The transcribed data was analyzed looking for NOIK and NOS and aspects, indigenous games, and peddle game based integration pedagogies. A Kitic analysis technique was used. Kitic analysis is a pragmatic tool that draws analytical techniques from qualitative content analysis, grounded theory and conversational analysis to deductively and inductively analyze data [6].

1.Analysis for NOIK and NOS Interface for Subject Matter for School Science

The data segments or units of analysis that spoke to each of the knowledge dimensions -Enterprise, Paradigm, Process and Product- were searched for in the data, re-examined and clustered into sub-categories of each these knowledge domains.

2.Analysis for Indigenous Games

The data analysis here was three pronged. First there was an effort to identify indigenous games. Second it was important to characterize the game. Thirdly, a selection had to be made of the game to use for illustrating how indigenous games could be used to integrate NOS, NOIK and STEM in classroom science. The definitions of indigenous games in the literature guided this process. Indigenous games reflect traditional and cultural aspects of the life of people within a specific locality [24]. The term 'traditional' here means the generational transmission of the game among a particular group of people from early human settlement in the community to date. Indigenous games, communicate socio-cultural identities of ancient times [25]. For illustrative purposes, the peddle game was selected and is used for this paper.

3.The Peddle Game Analysis for STEM, NOIK, and NOS Content

These analyses were informed by the literature conception of each subject discussed in the theoretical frame in section II above. In addition, STEM was recognized as grounded in NOS. Basically this is because all the STEM fields engage in scientific ways of knowing. Further, these analyses tapped from an understanding that science and mathematics generate theoretical knowledge that technology and engineering put into practice [26].

4.Peddle Game Based Integration Analyses

The analyses generated major peddled game based integration codes shown in Fig. 2.

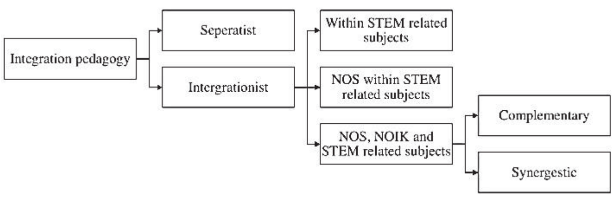

Fig. 2 Integration pedagogy codes

Separatist STEM pedagogy relates traditional teaching approaches. Within STEM related subject integration relates to an approach that guides the teacher to connect the content of his or her teaching subject to other subjects. NOS integrating teaching implies the teaching that makes effort to connect NOS and one or two STEM subject content within the western scientific boundaries. Across integration is two tiered. The complimentary approach in one level not only recognizes the similarities between NOIK and NOS where they interface but also the space where STEM related subject content could be drawn. The synergistic integration informs teachers into pedagogically thinking about NOIK and NOS common aspects that can be combined in a way that it is impossible to distinguish them from each other and comprehensible to learners.

IV. Findings and Discussion

For this study, the two major objectives were to: determine STEM related subject content that could be drawn from the NOIK and NOS interface and to find out how indigenous games could be used to integrate NOIK and NOS content in the teaching of a STEM related subject. Within this process the NOIK and NOS interface was interrogated. Interviews were used to diagnose each individual teacher's understandings of NOIK and NOS. Follow up dialogues were used to guide teachers in sharing their understanding of the natures of these knowledge bodies and help each teacher to develop a PCK. The findings from our investigation are presented and discussed below:

A. NOS Subject Matter Knowledge

Initially, the teachers held varied and common language expressions of NOS. Some of these expressions include: the knowhow of the environment and changes taking place in it, knowledge exists everywhere, in every locality regardless of humans being aware of it; knowledge developed systematically in response to societal problems, knowledge is constructed by scientists based on data and prediction. The dialogues helped in–service teachers to relate technical language descriptors of NOS to their initial common language discourses. The excerpts below from the in-service teachers illustrate what recurred across dialogue sessions.

- *Kuda:* It is difficult to describe science technically without reading about it in the literature… even without professional guidance… our training programs ignored these vital aspects…they focused on what we now know as product and process content, but more of product... we can now analyse what we said before and relate to the appropriate element of science. For example, right here in my transcript I said science is the knowhow of the environment and changes taking place in it. This relates to creativity, inquisitiveness and observation.
- *Tadi*: I viewed science as a way of doing science involving scientific steps to prove changes that occur in our environments through practical investigations. This relates to the empirical, predictive and inferential NOS
- *Tindo:* I too can pick on my seeing of science as existing everywhere and in every locality regardless of humans being aware of it as describing the universal and objective NOS.

From the analysis of their common language characterization in relation to literature, the in-service teachers proposed eight aspects of NOS that could form part of secondary school subject matter. Further, they categorized these NOS features into the four dimensions of science. These dimensions were overlapping and interfacing rather than exclusive.

1.Organizing Principles/Paradigm

The in-service teachers described the tentative NOS as a principle or belief that science is not fixed but rather changes in respond to current societal changes, challenges and needs, which the existing knowledge is limited to address. For example, they cited climate changes, health related problems such as HIV-AIDS and Ebola which call for new approaches (knowledge, skills and technology) to solve. They brought out that the activities of science focus on the physical environment because it is based on the observations made in the environment; and that NOS is tangible. Further, they suggested that NOS could be described as probable or inferential and that it is constructed out of human inquisitiveness, imaginations and creativity. They also suggest that science was underpinned by the principle of uniqueness because of its distinct language, and the nature of it as a human enterprise. Approaches to knowledge construction were also mentioned.

2.Habits of the Minds/Enterprise

That the in-service teachers were able to describe NOS from the enterprise point of view and that science knowledge development involves human values, imaginations, creativity, and inquisitiveness within a specific group of people is illustrated by the following excerpt.

- *Neo:* Scientist could be chemists, physicists, biologists; engineers …even medical doctors developing knowledge related to their fields… in simple terms they form a group which shares interest in a particular area…they develop a culture that guides them in developing this knowledge… those in science are intelligent enough to inquire and innovate.

3.Skills and Procedure/Processes

The sampled in-service teachers operationalized NOS in the context of processes or methods of producing knowledge. They used common language to express NOS in this dimension. These included what scientist do, the activities of a group people working in science such as biologists, and experimental approaches. For example, Musa summed up this component in the dialogue by pointing out that "scientists use their knowledge and skills to experiment through acceptable procedures". While the South African in-service teacher participants characterized the scientific processes as scientific inquiry their Zimbabwean counterparts referred to these processes as comprising the scientific method. A typical example is Tindo who described the knowledge production process as "discovered through the scientific method that aims at proving predictions arrived at through observations and literature reading". This suggests an understanding of NOS as empirical, predictive, verifiable and replicable.

4.Knowledge/Product

All the in-service teachers agreed that scientific knowledge (concepts, ideas, laws and principles) were generally durable and tentative, objective and universal, compartmentalized and expressed in technical language reflective of the discipline. They provided several examples of discipline based product knowledge such as enzymes in Biology, forces and motion in Physics, the Archimedes principle in Chemistry and Pythagoras theorem in Mathematics.

B. NOIK Subject Matter Knowledge for School Science

The in-service teachers held common understandings of indigenous knowledge which they expressed in non-technical language. Some of the expressions they used include:

- African knowledge
- A way of life possessed by a particular group of people and is unique to that group
- Knowledge confined to a particular place because it is connected to cultural practices
- Knowledge used by a specific culture to live their everyday lives and survive.
- People's knowledge

During dialogue sessions, the teachers' suggested six aspects of NOIK that could form part of secondary school subject matter and categorized them into four dimensions as discussed in the following sections.

1.Organization Principles/Paradigm

The in-service teachers were able to figure out the holistic, survival, spiritual functional and context specific NOIK. They described holism as the connectedness of all elements of nature. For example, Lerato explained that the knowledge of the people has all elements in one because it is connected to the land, spirits, life, plants and everything. This is why there is life science, physical sciences, history, arts and in fact all subjects we teach in schools. Tindo explained that "the stable nature of knowledge can be inferred from its other name traditional knowledge. This simply means it has central aspects that are resistant to change".

2.Habits of the Minds/Enterprise

The in-service teachers' concurred that the construction of indigenous knowledge was guided by the *Unhu/Ubuntu* values. For example, Kuda said that "most of this knowledge has been constructed with the settlement of ancient people in their localities… they respected all elements of nature because they learned from nature to survive…They respected their ancestral spirits because they gave them wisdom to observe nature and modify knowledge to suit the current demands. This is what they passed on to us".

3.Skills and Procedure/Processes

Teachers figured out that indigenous people held multiple processes for constructing new knowledge or modifying existing knowledge to suit their current life. These included spiritual (dreams and visions) guided knowledge construction, empirical knowledge development, experiential knowledge construction (learning from plants and animals), and individual shared knowledge.

4.Knowledge/Product

The in-service teachers educated each other that indigenous knowledge (concepts, ideas, laws and principle) were generally durable and tentative, subjective, and expressed orally and metaphorically.

5.Indigenous Games

The in-service teachers revealed many games which are listed in Table III.

TABLE III
INDIGENOUS GAMES

Zimbabwe	South Africa
Pada	Ingqutu
Nhodo/Nhamo	Uxgha
Rakaraka	Amathini
Pfuva/tsoro	Umufila Bhande
Chitsvambe/Chisweru	Izingedo
Chamutsunye mutsunye	Diketo
Mahumbwe	Kgathi
Chuti	Dibeke
Dudu muduri	Murababaraba
Kusika nyimo	Mathini
Pakasungwa neutare	Mogusha

Many of the games, for example,Pfuva/Ncuva, Murabaraba/ tsoro, and Nhodo/Diketo were common to the two nations.

The peddle game or Nhodo/Diketo was chosen to illustrate how games can be used to engage teachers with STEM content, NOIK content and NOS content in the same classroom science space. The game has a rich tradition throughout Southern African indigenous communities. It is named in indigenous language of each tribe and with unique variations. The game is played from a sitting position by one player for practice and two players for competition. The players are not allowed to shift positions until game over.

In Zimbabwe, the players use seven stones while in South Africa ten to twenty stones are used. Each player needs one big and almost spherical stone known as the ghoen. The other remaining stones are almost spherical and of the same size. The players pick the stones in their locality and avoid picking the stones from sacred places such as areas around sacred pools and in graveyards.

The players dig a small hole in the ground under a tree or besides a hut or building. The small hole is approximately 10 cm diameter and 5cm depth. Normally, this game is played in the afternoon between household daily chores such as working in the fields, cooking, fetching water and cleaning plates. This is regarded as resting time after lunch. Two players sit opposite to each other. They set the rule for the first to play because the starter has high like hood to win the game. The starting rules vary with players. Three main starting rules emerged from the data: by consensus; coin tossing and when the flip result is head or tail the one with the resultant choice plays first; and exchange rule for regular pairs, the first to play in the last game becomes the second to play.

The first player throws the ghoen up, pushes or scoops out the stones in the hole before catching the ghoen. If the ghoen is caught, the player throws it up again, pushes the stones back into the whole and leaving one out. The play continues in this way until all the stones are possessed by the player. At this point the player throws all the seven stones up and attempts to catch them with the back of the hand. If the player catches them all, he or she repeats this until some stones drops to the ground. The numbers of stones caught are scores that the player adds up. When some stones drop to the ground, the player starts the game from the hole until the player fails to catch the ghoen before scooping out all the stones. If at any time this happens, the other player has a turn.

The winner is the player who has the highest scores at the end of the game. The game may end either when intercepted by elders' call for time to go back to home chores or player demotivation and ends the play or because of player exhaustion.

C. NOIK Aspects in the Peddle Game

The locale aspect of NOIK was identified from the game played in the locality and natural setting of the players. The players pick peddles in the local community but avoid picking them in sacred places. This revealed the spiritual dimension of NIOK. Teachers were also able to pick up the holistic NOIK in the game. They established that playing the game required linking elements of nature. Players are the human elements that drew recreation from the game using natural resources of stones, ground/land and trees or building. Teachers established that the positioning of the play under a tree or a building was based on the idea of being under a shade since the game is played mostly in the afternoon. The hole is dug in the ground. The stones are picked in the locality; the game is played in between home chores. In putting together natural resources for play they respect sacredness. In addition, playing the games requires scientific knowledge and skills embedded in indigenous knowledge. The players of the game reflect an enterprise with common interests and guided by game norms. The value of respect, openness, honest, co-operation and perseverance were inferred from the norms of play. For example, the start rules show mutual understanding and respect. The duration of play, rounds of the game and the playing over several days are all signifying determination and perseverance. Other aspects of NOIK which the teachers identified included orality and stability.

1.NOS in the Peddle Game

The teachers related the game's norms discussed above to habits of the minds also shared among members scientific enterprise. The game play has explainable aspects in terms of the sports recreation and scientific principles. The teachers established the discipline based NOS through identification of concepts related to different scientific fields.

2.STEM Subject Related Aspects in the Peddle Game

Table III lists several STEM subject-related content that the teachers extricated from the peddle game.

The teachers established that the range of STEM related concepts in the game potentially lay a strong foundation for making engineering and technology concepts explicit in the same classroom science spaces. For example, Tindo explained that "in playing this game we unconsciously combined concepts from all the scientific disciplines to concentrate and make winning decisions". Kuda added that "the knowledge and skills the game demands prerequisite the critical thinking needed in engineering and technology …architectural designs tap from mathematics, geography, physics, and chemistry. African technologist such as blacksmith, sculpturing, wood crafters and basket or mat makers apply scientific and mathematical reasoning in their works". Lerato in a South African dialogue session added that the peddle game demands co-operation, concerted effort and discipline"

TABLE IV
STEM SUBJECT RELATED CONCEPTS IN THE PEDDLE GAME

Subject	Concepts extricated from the peddle game
Biology	Body movement, microbiology, pulse rate, enumeration, balancing, respiration
Chemistry	Reaction time, sample treatment, separating substances, balancing
Geography	Weather and seasons, soil texture, and conservation of natural resources, properties of stones, celestial bodies, time and shadows.
Mathematics	Probability, counting, addition, subtraction, multiplication, shapes and angles, geometrical construction, projectiles, balancing
Physics	Time, velocity, force, gravity, friction energetics, gravitational force, speed, force, motion, balancing
Scientific skills	critical thinking, concentration, collaboration, endurance

D. Peddle Game-Based Integration Pedagogies

The dialogue sessions revealed five pedagogical ways which STEM, NOS and NOIK could be integrated from the peddle game.

1.Separatist Integration

The teachers noted that the concepts allied to STEM related subjects extricated from the peddle game could be taught parallel to each other but could be linked to engineering and technological practices through field trips and research approaches to teaching. For example, Lerato was concerned that "without development programs on engineering, technology, mathematics and other science subject content the teaching remains subject based"

2.Within STEM Related Subject Integration

The within STEM related subject pedagogy was described as a separatist pedagogy. Using this approach teachers identified concepts in peddle game cutting across STEM subject related subjects. Teachers established that STEM related subjects could be integrated by interrelating three strategies: paying attention to the subject context meaning of such concepts as balance and time, deliberate searching for connection of the concepts across science subject and mathematics, and establishing the practical application of such concepts in various technological and engineering fields.

The Zimbabwean participants used the concept of balance to illustrate how this within STEM related subject pedagogy can be used in different subject areas. Tadi identified the concepts of ecological balance, skeletal balance, and mineral balance in biology. Kuda picked up chemistry concepts of chemical equilibrium and balancing of equations. In physics, Tindo identified the concept of balance in momentum physics and torque equilibrium. Tindo explained that "the concept of balance emerged from the peddle game. It is easy to imagine how each group of scientist developed it in their discipline language and to connect the concept across the STEM subjects and its applications to industrial processes…I can think of architectural designs which are interdisciplinary in nature…we can teach the concept from its application. This approach clearly connects across sciences and mathematics".

Clearly this pedagogy taps from an indigenous game and connects concepts across the STEM fields but does not make reference to neither NOIK nor NOS.

3.Within STEM Subjects NOS Integration

Another pedagogical approach that stemmed from the peddle game was what the teachers labeled within STEM subjects NOS integration. The teachers started by identifying cutting across STEM related concepts in the game. The South African teachers used the concept of time. They followed this by identifying NOS aspects from the peddle game to teach with this concept. The South African participants picked tentativeness, empirical creativity and durability aspects of NOS. These teachers then identified the concept of time in the context of each STEM related subject:

- Geography time: day, nights, seasons and years, population growth
- Biological time: gestation periods, growth and development and pulse rate.
- Chemistry time: rates of reactions and reaction time.
- Physics time: Motion physics.

Like in the balance illustration above the South African participants went on to identify discipline related industrial applications. The agreed that it was from industrial applications the NOS aspects could be introduced. For example, Neo explained that "the creativity and tentative NOS is seen in the history and development of steam engines. Obviously, time and speed was a big problem that drove the improvements we see today". Musa suggested tracing the history and development of the clock time people are using today: "When we read about this in literature NOS aspects are easy to see but you need to know what you're looking for."

4.Complementary NOS, NOIK, and STEM Integration

Teachers labeled the fourth pedagogical approach summarized in Fig. 2 that emerged from the peddle game complementary. Teachers identified many ways they could adopt this pedagogy in their classrooms. Tindo presented how one of the strategies could be used to teach about time in lesson structures as follows:

- Lesson 1: Time and speed in mathematics
- Lesson 2: Time and speed in motion physics
- Lesson 3: Time and speed in chemistry- rate of reactions
- Lesson 4: Time and Speed in biology- pulse rate
- Lesson 5: Time and Speed in Geography- wind
- Lesson 4: Science perspective of time
- Lesson 5: Indigenous perspectives of time

This teaching approach connects the concept of time within STEM related subject in the intersection. Moving out of the intersection to the left the time concept is taught from a cultural perspective to explicitly bring out NOIK aspects. The converse is true when the teaching moves to the right, it explicitly brings out NOS aspects. This teaching can be accomplished by use of field trips, research and presentations.

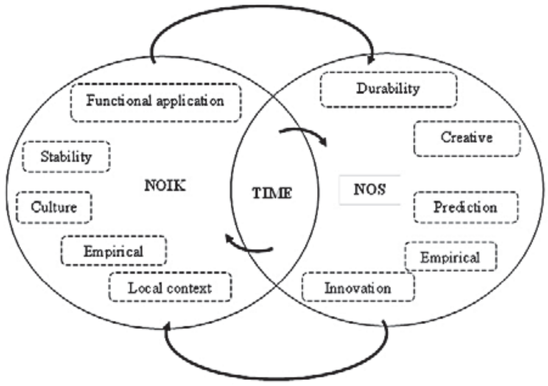

Fig. 3 Complementary NOS, NOIK, and STEM integration

5.Synergistic NOS, NOIK, and STEM Integration

Teachers also identified the synergistic NOS, NOIK and STEM integration pedagogy. However, they were quick to point out that this was an ideal approach that was practically complex to implement at classroom level.

II. Conclusions and Implications

Researches in NOS, NOIK, and STEM Education have been largely done separate to each. This study is unique in that it brings together these three stands, the results from this study provide insights into NOS, NOIK and STEM subject content that could be taught in science classrooms and indigenous games grounded strategies which could be adopted integrate these aspect science teaching. The results indicated that the teachers improved their understanding of NOIK, NOS and STEM Education. They were able to suggest of different aspects of NOS, NOIK and STEM as well as alternative pedagogies for their integration.

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