Keiyo Cattle Raiding, Kechui Mathematics and Science Education: What do They Have in Common?

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ABSTRACT: In the context of globalization, indigenous educational systems of endangered cultures are faced with extinction. Biologists recognize that biodiversity is dependent upon sustaining and promoting knowledge and values of indigenous cultures. Education researchers have a similar responsibility – to promulgate educational diversity before several thousand years of valuable educational knowledge is extirpated. This paper presents the Keiyo of Kenya who have a rich educational system. Its focus is on an indigenous game, *Kechui* (using calculations to sharpen your mind), based on cattle raiding, and the Keiyos' use of the game for learning mixed strategy-based probabilistic problem solving. Kechui may also have international potential for teaching probabilistic problem solving in contemporary mathematics and science, especially genetics.

KEYWORDS: Cattle raiding, cultural extinction, genetics, indigenous education, Kalenjin, Kechui game, Keiyo, Kenya, mathematics, problem solving.

In the dawn of a new millennium, economically dominant cultures are emphasizing that technological globalization (framed in their agendas) is essential to every Nation's survival. A problem is that at a much more fundamental level of survival, indigenous knowledge systems and one-half the world's 6,000 languages (2,400 are endangered and 50% are considered dying) are facing rapid extirpation (Brenzinger, 1992; Krauss 1992; Wass, 1999). And, given the present agenda for the rapid technological globalization of knowledge that is taking place, further jeopardy and stress are being placed on our global cultural heritage. Whether intentional or not, the world's exponentially growing computerized knowledge base and information is commercially

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controlled and focuses on Western economic interests. Hence, in its current form, cultures are neither equally valued, nor are there adequate provisions for equity in this new globalization structure (Cox, 2000).

However, if in the process of globalization, computer technologies are used decorously and can find a cultural fit, they may serve as an integral component for offering solutions and saving endangered cultures, rather than serving as problematic agents aiding in their demise. In this regard, it is imperative that educational diversity as well as biodiversity be appreciated, understood, maintained, and promoted globally such that all peoples are allowed to exist, and co-exist, harmoniously (Bray, Clark, & Stephens, 1986; Cox, 2000; Gerdes, 1995, 1999; Hess, 1995; Samoff, 1996). Indeed, indigenous cultures and cultural identities are agreed upon to be fundamental human rights (Ayton-Shenker, 1995) and global technology should be used effectively to help promote these indigenous knowledge bases. Accordingly, rather than creating an education monolith based on idealized conformity to one set of international standards (e.g., Third International Mathematics and Science Study – TIMSS, 1999), it is necessary that education be inclusive of diverse thinking. Alternative educational views need to be continuously examined and their worthwhile contributions promulgated. And, subsequently, indigenous knowledge systems and values may be recognized as global resources, rather than being viewed as antiquated and localized primitive liabilities.

In Africa, remnants from the colonial period and a general lack of viable research that can inform educational and social transformation continue to challenge the continent as we embrace the 21st century. Problems currently facing Kenyans with regard to the country's educational system and curricular motifs (Totally Integrated Quality Quality Education and Training – TIQET, 1999) provide one more vivid example that is certainly not unique within Africa (see Samoff, 1996). With the replacement of a British 7-4-2-3 system, first introduced in 1948 (Eshiwani, 1993) and reintroduced in 1966 (Shiundu & Omulando, 1992), with the current controversial Canadian/United States 8-4-4 system introduced in 1985 (Eshiwani, 1993) paralleled with continuous curricular adjustments, it is déjà vu. After a 15 year tenure, Kenyan educational policy directives are considered to be in a crisis state and once again are being revamped (Aduda, 1999). Although the intent of our research began prior to Kenya's current dilemma, our conclusions come at an opportune time when Kenyans are looking for a new direction.

In this study, there were four research foci:

1) to examine an indigenous Keiyo (a Kalenjin ethnic group in Kenya) matrix game, *Kechui* (using calculations to sharpen your mind) that requires use of concepts for counting, estimation, and probability;
2) to decode the historical cultural context of the game;
3) to assess culturally-based cognitive strategies used in playing the game; and,
4) to ascertain specific connections to classroom-based transmission genetics (mathematics) problem solving, especially in relation to computer generated open-ended problems.

While conducting this study, it was realized that Keiyo education was also undocumented. Consequently, this paper presents (a) an introduction to indigenous Keiyo education, (b) a description of strategies used in cattle raiding, (c) a description and rules for Kechui, (d) strategies Keiyo secondary school students use in playing the game, and, (e) a summary of Keiyo secondary students' success in solving textbook versus computer generated transmission genetics problems.

The significance of this research lies primarily in its direct concern with the current dangers of cultural extinction as well as being an initiative to develop a new way of conceptualizing integrative education that is indigenous to Africa, and for Kenya, in particular. Equally significant is that this study offers a deeper understanding into the nature of learning mathematics problem solving through a cultural perspective as embedded in an indigenous game, Kechui. The game has its origins in traditional cattle raiding, a highly regarded enterprise among East African pastoralists (Anderson, 1986; C. Murei, personal communication, July 23, 1999; Fleisher, 1999). Given the background of current Kenyan educational reform, this study advocates that Kechui be utilized in Kenya's formal national science and mathematics secondary curricula as a culturally significant and credible indigenous game for exploring and learning about mathematics/genetics-based problem solving. Mathematics and transmission genetics problem solving require use of inductive strategies analogous to those utilized in playing Kechui. There are no known studies linking students' use of strategies for solving mathematics and science (in this case transmission genetics) problems in relation to an indigenous African game.

In the context of this study, the documentation, preservation, and promotion of indigenous educational systems, vis à vis cultures and languages, are viewed as critically important as biologists' recognition for the linkage of indigenous knowledge systems to species preservation

(Cox, 2000; Fratkin, 1996; Goldschmidt, 1996; Juma, 1989; Plotkin, 1994) and prevention of indigenous crop extinctions (National Research Council, 1996). In this frame of thinking, the intent of this study is not only to preserve the Keiyo people's game of Kechui for use in teaching and learning science and mathematics in Kenya's schools, but also for historical preservation of Keiyo culture. Besides, Kechui may have the potential to offer other cultures a game of probability for helping students to learn mathematics and transmission genetics. Finally, Keiyo language is unwritten and, as such, this study represents an attempt to formalize Keiyo vocabulary in a written form to assist in preventing cultural extinction.

Theoretical Frameworks

Keiyo learning theory along with situated-learning theory (Butterworth, 1992; Light & Butterworth, 1992), constructivist frameworks (Steffe & Gale, 1995), game theory (COMAP, 1994; Kuhn, 1997), and mathematics problem solving heuristics (Polya, 1971) were used to guide this research. Additional theoretical perspectives used include second language acquisition and use (Rollnick & Rutherford, 1996; Vygotsky, 1992), and socio-multiculturalism (Gay, 1995).

Keiyo learning theory is based on *ng'omnon* (knowledge) through *ipwaat* (to think, remember, recall) and *inai* (coming to know or understand). Interrogatives are valued components of the learning process: What? (*Nnee*?), How? (*Uunee*?), Why? (*Amunee*?), When? (*Auyoo*?), Who? (*Ng'o*?), and Where? (*Olebono*?). The Keiyo learning theory is essential for understanding extant culturally-based education and interpreting strategies Keiyos' use in problem solving whether it be in cattle raiding or playing Kechui. Knowing Keiyo culture is also important for constructing conjunctive linkages if one is to integrate valued indigenous knowledge into existing exogenous education curricula. Furthermore, some Keiyo concepts and experiences are contextual and have no direct equivalence with the English language so justification must be established for their inclusion in the curricula. For example, concepts used for age set identifications (e.g., *Korongoro*) or a Keiyo home and its environment emphasizing the presence of cattle (e.g., *beutab tuga*), have no suitable translation. Or in science, a plant may have English (e.g., Sodom Apple), Keiyo (*lobotwa*), and Latin (*Solanum incanum*) names, but the plant's use is particularly meaningful to the Keiyo (e.g., the fruits of *lobotwa* are used to represent cattle (*tuga*) in several societal functions. Educational inclusion of indigenous names and unique ways of thinking gives value to cultural knowledge that long precedes the arrival of Europeans. An English language only dictum further implies that Keiyo concepts (and knowledge) were awaiting colonization to gain official recognition in accordance with an English understanding, explanation, or discovery.

Situated-learning theory permits exploration and interpretation of interactions made within an educational environment in order to determine how, what, and why students create unique knowledge. For example, Lave (1992) posits that informal (everyday life) and formal (school life) contexts both provide situated sociocultural learning environments. From a constructivist perspective, knowledge is not passively received, but actively engaged in by learners (Ausubel, Novak, & Hanesian, 1978; Steffe & Gale, 1995). In this context, a learner's prior experiences and knowledge are essential factors in determining what and understanding why some concepts are learned, other concepts are not valued as necessarily relevant, useful, or important, and still others not understood (Hodson, 1998; Posner, Strike, Hewson, & Gertzon, 1982; Saxe, 1995). Knowledge is understood to result from "transactions between social knowledge and personal knowledge ... with the former being an objective accumulation of previous human cultural experiences and the latter being the accumulation of an individual person's subjective life experiences" (Kolb, 1984, p. 36). Hence, the deconstruction of experiences as related to emotions, feelings, and relative to a given situation, are intertwined with the cognitive strategies used, and is consistent with the theory of experiential learning. In this frame of reference, knowledge is also viewed as "a process whereby knowledge is created through the transformation of experience" (p. 38) and reflects a continual change that depends on the social and cultural environment in which one is situated. Decontextualizing formal education in science from a child's experiences was first critiqued by Dickens's (1854) social commentary *Hard Times* and reiterated by Whitehead's (1927) criticism of education stating: "let the main ideas which are introduced into a child's education be few and important, and let them be thrown into every combination possible ... from the very beginning, the child should experience the joy of discovery" (p. 3).

In countries outside Africa, students' understanding of scientific knowledge from a constructivist framework has received considerable attention from some mathematics (Steffe & Gale, 1995) and science (Glynn, Duit, & Thiele, 1995) education researchers. And, in instances, scientists' problem solving (geneticists) knowledge and strategies have been documented from a historical perspective (Darden, 1991) and in a dynamic simulation enviroment (Thomson, 1993). All problem solving requires use of strategies and each problem solution is context and content specific. Some strategies may be routinized and the solution pathway can be stated as an algorithm. Others, especially solution pathways for non-routine problems, require the use of heuristics. Cognitive strategies as related to problem solving, particularly in connection with tasks involving probability are difficult ideas for students to comprehend in mathematics (Gerdes, 1995; Saxe, 1995) and genetics (Thomson & Stewart, 1985; Thomson, 2000) secondary education. In Africa, one way to bridge students' understanding of heuristic problem solving may be through the use of indigenous probabilistic games rather than relying on "coins and die." Indigenous African games have traditionally served valued cultural functions such as the development of cognitive, psychomotor, and social skills, and promotion of environmental awareness (Gerdes, 1995, 1999; Chepyator-Thomson, 1990; Zaslavsky, 1990). Understanding students' cognitive strategies as used in indigenous games may offer linkages useful in developing ways students can comprehend and construct subject specific content knowledge through "cultural conscientialization" (Gerdes, 1995).

In the context of sociocultural educational perspectives, Luria (1971) has previously recognized that to understand thinking and learning in a culture, it is imperative that one investigates the "relations among objects, tools, and language which have been laid down in the course of social history" (p. 260). Ogunniyi (1988) offers that every human "tends to resolve puzzles in terms of the meanings available in a particular sociocultural environment, the baseline is that the meanings become firmly implanted in the cognitive structure ... and may act as templates, anchors or inhibitions to new learning" (cited by Jegede, 1994, p. 123). Säljö (1998) suggests that within cultures, societal members must master two major categories of tools: "practical (or physical) tools and psychological (or intellectual) tools" and the "link between mental and physical tools must be understood as discursive in nature ... [as they] are manifestations of human conceptual distinctions that originate in human activities" (p. 42). Accordingly, more lasting learning occurs when contextually rich learning environments are constructed to promote problem-solving abilities in students (Gruender & Tobin, 1991). Competitive game situations appear to be sociocultural universals and are used to present puzzles, dilemmas, and problem solving situations in which there are gains and losses between two or more individuals. Embedded within numeracy-based games are mathematics' dilemmas and problems. The study of games is included in a branch of mathematics known as game theory (Kuhn, 1997). A game consists of sets of moves between players. A strategy is a set of moves which a player plans to follow while playing a game. Each player is able to act freely and select from a finite pool of options or moves (pure strategies), dependent upon the game's algorithmic rules, that lead to a particular outcome (rewards or penalties).

Most competitive games are dynamic and thus, require changes in strategies resulting in unpredictability, variability, and promote risk-taking on the part of each participant. As such, these games promote a collection or series of moves, together with a corresponding set of weights, which inculcate probabilistic thinking and incorporate elements of surprise through the use of mixed strategies. A mixed-strategy, then, is a particular randomization within a players' repertoire of pure strategies implemented to create surprise for the opponent. Each strategy has a particular optimization, relative frequency, and level of use depending upon a player's knowledge and experience (Fudenberg & Levine, 1993; Gintis, 2000) . Strategy implementation is also dependent upon the game's current status created by the opponent's moves as perceived by a player. Further, because each player can use mixed strategies, "the resulting outcome of a game can not be predicted in advance, but it can be described in terms of a statistical notion of average or expected value" (COMAP, 1994, p. 469). A two-person, zero-sum game that can be described by a matrix is called a matrix game. A zero-sum game is one in which the reward to one player is a penalty to the opposing player.

There may exist an analogical linkage domain between playing Kechui, Euclidean mathematics, and transmission genetics problems because they integrate counting, estimation, and probability-based problem solving using matrices. First, Polya (1971) argues that Euclidean mathematics problems presented in a heuristic mode "requiring inventing or making, appear as an experimental, inductive science" (p. vii). He identifies two kinds of mathematical problems: (a) 'problems to find' are inductive and involve searches for unknowns including games, whereas, (b) 'problems to prove' are deductive and examine or test assertions and hypotheses (p. 154). Second, globally all primary level life-science and secondary level biology courses introduce problem solving in transmission genetics using Mendel's (1866) classic explanations for pedigree inheritance patterns found in peas (*Pisum sativum*). Transmission genetics (versus population and molecular genetics) includes probability-based investigations relating observable traits (e.g., pea seed color) with respect to phenotype variation (e.g., green or yellow). The causal agents are the contributions determined by the relationship (dominant, codominant, and recessive) of paired alleles (genotype). Transmission genetics problem solving requires use of probability matrices (Punnett squares or probability trees), including a 4 x 4 matrix for typical dihybrid problems. Kechui is a probability-based mathematical matrix game that requires use of a 4 x 4 matrix playing board. In this study, students were asked to solve textbook and computer generated transmission genetics problems (Genetics Construction Kit, see BioQuest, 1999). Real world and dynamic computer generated (BioQuest, 1995) transmission genetics problem solving is (a) inductive, going from effect (observable phenotypes) to cause (allelic relationships) and, (b) deductive, cause to effect (deductive hypothesis testing) and requires probability-based mathematics problem solving.

Finally, another perspective used to guide this study is a multicultural theoretical framework which offers a conceptual view to understand, appreciate, and sensitize one to educational diversity (Gay, 1995; Banks & Banks, 1993). In this sense, learning in a global community occurs in culturally rich niches and understanding is expected to extrapolate to the scale of the biosphere. Thus, with the realization that the new millennium will bring challenges requiring innovative changes in the nature of education, understanding children's culturally based cognitive structures and problem solving strategies relevant to their acquisition of discipline specific content knowledge is paramount.

The Keiyo People

Kenya is approximately 582,647 square kilometers in size and straddles the equator. Kenyans share over 40 major languages. However, many Kenyans are trilingual as English is the official language, *Kiswahili* is the national language, and each ethnic group has a "mother tongue." The Keiyo (1990 pop. about 120,000) are one among eight Kalenjin ethnic groups in Kenya. The Keiyos' area of residence (Figure 1) forms today's Keiyo District (south-north length = 100 km, west-east width = 20 km) in Rift Valley Province of northwest Kenya and is situated between latitudes 0° 20' to 1° 30' North and longitudes 35° 0' to 35° 45' East. Keiyo Escarpment runs south-north through the district and west-east, links the cool (12-12 °C mat) moist Uasin Gishu Plateau (2600 m asl) with the warm (22-24 °C mat) semi-arid Kerio Valley floor (1250 m asl).

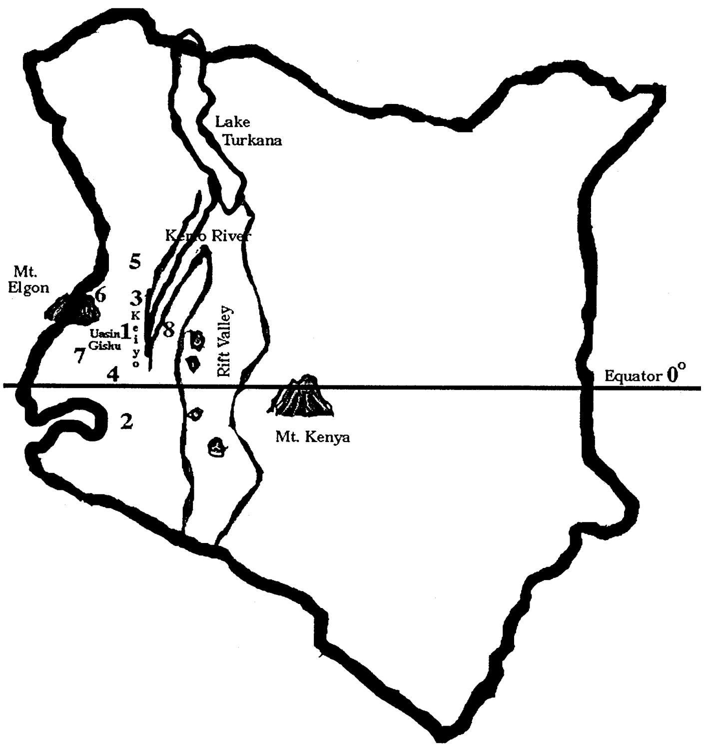

Figure 1. Map of Kenya showing the relative location of the Kalenjin groups. (1) Keiyo; (2) Kipsigis; (3) Marakwet; (4) Nandi; (5) Pokot; (6) Sabaot; (7) Terik; and, (8) Tugen.

The origins of the Kalenjin people and language is considered southern Nilotic and has been dated to at least 5,000 yBP (Ehret, 1971). The first documented encounter of Keiyos with a European explorer was the passage of Joseph Thomson (1887) in November, 1883. On his journey, in search of the great lake to be named Victoria Nyanza, he met the *Elgeyo* (a name given the Keiyo by the *Maasai*) in Kerio Valley, traversed the Kerio escarpment, and continued westward on to the Uasin Gishu plateau. In 1891, the German Emin Pasha Expedition tried to follow the same route and encountered Keyu (the German spelling of Keiyo) resistance on the escarpment (Peters, 1891). The explorers' proclaimed transient intentions, contradicted by the killing of Keyu warriors, initiated prolonged mistrust of Europeans (Massam, 1927).

Methods

Subjects and Data Collection

Duit, Treagust, and Mansfield (1996) posit that investigating students' conceptual understanding is a "prerequisite to improving teaching and learning in science and mathematics" (p. 17). They reviewed several methods that are useful for investigating a person's conceptual understanding including naturalistic settings, interviews, test items, and computer generated problem solving environments. Their suppositions are consistent with methods for naturalistic inquiry as advocated by Lincoln and Guba (1985) and used in this study.

Four pastoral elder (age set *Chumo*) Keiyo males were video-taped as they described Keiyo education and their experiences in cattle raiding when they were young males of warrior age. They were also asked about Keiyo knowledge and practices concerning biological inheritance and the raising of cattle. The elders were not asked to play Kechui as it is considered to be a game played prior to initiation into manhood, however, they were able to describe its educational role in Keiyo culture.

Sixteen Keiyo Form IV students (8 females, 8 males) in two secondary boarding schools were randomly chosen to participate in the study. All had completed the relevant mathematics and genetics topics as outlined in Kenya's national syllabi and biology textbooks (Kenya Institute of Education – KIE, 1992; Kenya National Examinations Council – KNEC, 2000). To assess baseline genetics knowledge, each was given 13 multiple choice and two structured questions from past Kenyan national examinations. Problems included meiosis, complete and codominance, sex-linkage, monohybrid and dihybrid crosses. Next, they were interviewed and audio-taped as each solved two Genetics Construction Kit (GCK) transmission complete and codominance genetics problems (BioQuest, 1999). Subsequently, they were randomly paired to play one another in Kechui and video-taped. The winners and losers were interviewed twice at the completion of their game to review strategies each had used. The first interview was to describe their general strategies and the second included a video-tape review to determine strategies each had used for specific rounds and moves.

Data were collected in the language participants felt most comfortable (English, Kiswahili, or Keiyo). While Keiyo elders used Keiyo language for the interviews on cattle raiding and Kechui, the secondary school participants chose to use Keiyo or Kiswahili when playing Kechui and used English for describing their problem solving strategies in transmission genetics. All interview data were transcribed. Keiyo elder males' description of indigenous education and strategies used in cattle raiding, rules of the game, and student's strategies used in playing the game were translated.

Data Analysis

The constant comparison method (Glaser & Strauss, 1967) was used for coding and comparing elders' and students' statements. For language analysis Toweett's (1979) study of *Kipsikiis*, another Kalenjin language, has been utilized. Statements were categorized using Polya's (1971) strategies for mathematics and Thomson's (1993) strategies for genetics- problem solving. In Polya's four-step sequence, the solver must understand the problem, find a connection between the existing condition (data) and the unknown leading to the construction of a plan, carry out the plan, and examine if the solution is a successful result (Figure. 2, 1.0-4.0). Thomson proposes that hypothesis construction, use, and revision for dynamic problems in which the data changes continuously, the solver uses four levels of hierarchical strategies each with a feedback loop. Strategy types (Figure. 2, 1.1-4.2) and general strategies (Figure. 2, 1.1.1-4.2.3) are useful for all problem solving. Exemplars are more specific strategies and are context and content/domain dependent. For example, the *beutab tuga* is an entity common to cattle raiding and playing Kechui. However, actions and moves concerning a beutab tuga will be different as to whether it is a safe location or site for potential raiding both in real life and in playing Kechui. Similarly, in transmission genetics and GCK problems, crossing of individuals with like and/or unlike phenotypes is performed at specific times. Finally, an example is the strategy invoked with regard to each action, move, or genetic cross made while solving a problem. The number of rounds, subrounds, and moves used by each student were also counted. In using these methods, common and comparative strategies used in cattle raiding, game playing, and genetics problem solving emerged. In the results section, elders' and students' statements are referenced in brackets, with respect to strategies presented in Figure 2. For example, one elder stated "there was famine [1.1.1] ... people of this area gathered together to talk for the purpose of deciding when they would travel [1.1.2]" is first, identification of an unexplained state, and second identification of specific rules and procedures that must be followed. For brevity and because of space limitations, the quotes presented are selected to demonstrate strategies used.

Figure 2. *A Hierarchical List of Steps, Strategy Types, and General Strategies Used in Problem Solving.*

In dynamic problem solving, a solution pathway is often nonlinear, and thus, requires recurrent feedback as each strategy is evaluated.

1.0. *Understanding the Problem.*
  1. *Strategies for identifying a problem.*
    1. Identify an unexplained phenomenon (object, state, event, process, and/or change).
    1.1.2. Identify specific rules and procedures that must be followed.
    1.1.3. Determine a possible solution for the unexplained problem.
  1.2. *Strategies for producing ideas.*
    1.2.1. Identify qualitative variables.
    1.2.2. Identify quantitative variables.

2.0. *Devising a Plan.*
    Find a connection or pathway between the existing condition (data) and the unknown leading to the construction of a plan.
  2.1. *Strategies for producing ideas.*
    2.1.1. Identify and construct interrelations and/or preliminary patterns for the variables.
    2.1.2. Identify constraints.
    2.1.3. Identify people, objects, states, and conditions needed for implementing the plan.
    2.1.4. Identify possible actions and moves that can be invoked and their optimum conditions for implementation.
  2.2. *Strategies for data exploration.*
    2.2.1. Introduce a simplifying assumption, then complicate the problem.
    2.2.2. Create at least one known or standard for comparison.
    2.2.3. Restrict the problem space by considering a limited number of unknown variables at any one time.
    2.2.4. Identify and utilize models or simulations.
  2.3. *Strategies for hypothesis construction.*
    2.3.1. Construct working and null hypotheses.

3.0. *Carry out the Plan.*
  3.1. *Strategies of preparation for implementation.*
    3.1.1. Collect and assemble required people, objects and/or materials.
  3.2. *Strategies for implementation of plan.*
    3.2.1. Conduct an activity.
    3.2.2. Conduct a simulation.
    3.2.3. Conduct an experiment.

4.0. *Examine if the Solution is a Successful Result*
- 4.1. *Strategies for data analysis.*
  - 4.1.1. Compare qualitative outcome with expected result.
  - 4.1.2. Compare quantitative outcome with expected result.
  - 4.1.3. Compare combinations of outcomes with expected result
- 4.2. *Strategies for improving an outcome with an unexpected result.*
  - 4.2.1. Identify that an anomaly exists.
  - 4.2.2. Locate and evaluate the implications of the anomaly
  - 4.2.3. Develop new strategies for constructing a pathway with altered or new variables and constraints.

Results

Elder's Descriptions of Indigenous Keiyo Education

In Keiyo culture, an understanding of mathematics and science are embedded within the organization and structure of generations and kinship system (discussion of Keiyo kinship genetics problem solving are beyond the scope of this paper). There are eight cyclical age divisions of life-time and males and females have separate, but concurrent, age-groups. Each age-group represents one-half generation and has a name. Thus, between a father and son, there is an intervening age-group. For example, at present the very oldest men are *Maina* and are no longer required to actively attend clan meetings (although their input is always considered in decision making). The next age group are members of *Chumo* age-group and are the current elders who advise *Sawe* (sons of Maina), men of about 50 years of age who are collectively responsible for making the important community decisions through consensus building. *Korongoro* (sons of Chumo) are young men in their 40s and the men of warrior age are members of *Kipkoimet* age-group who, in the past would have conducted cattle raids. At the time of their initiation, today's young males will become *Kaplelach* and infant males will become *Kimnyegeu*. *Nyongi* age-group has no born representatives.

At marriage, a wife becomes a member of her husband's age-group. A mother is any woman on the child's maternal side and all of her brothers are uncles. A father is any man on the child's paternal side and any father's sisters are aunts. Oral records of kin relationships such as these are useful in determining genetic proximity and family histories. Subsequently the councils of elders (male and female) use the knowledge to make complex decisions when there is a discourse on a proposed marriage. Past social and psychological family compatibility are also considered before a marriage is permitted.

Keiyo culture has an educational system based on life-long learning in a society structured on cyclical age-groups. All Keiyo people have equal social status, however, each age-group has specific responsibilities which synergistically serve the welfare of the community. That is, for the Keiyo, story telling by an elder is as important to the society as someone involved in food production. In Keiyo society, a person's character is the most important measure of respect, rather than material possessions, including cattle. A person with respect is one who is truthful and upholds Keiyo rules and regulations governing behavior, such as, when there was war. For example, female elders would remove their traditional belts to signify the end of war and men would be required to oblige however hard the situation may be. In the Keiyo educational system, each age-group is expected to follow customary practices and to conduct their responsibilities accordingly. Keiyo education emphasizes consensus building through discourse.

In the Keiyo educational system, learning occurs informally, through work (*boisio*) or play (*ureren*), and formally through customary practices such as initiation (*tuum*) and marriage (*katunisiet*). In addition, the Keiyo make a distinction between teachers involved. Within the processes of informal education, at times a teacher (*kanetindet*) may spontaneously engage learners in learning as a situation arises. But, in other situations, learning is centered on particular tasks (*boisioshiek*), the relative time of day or night (for example: morning (*katil asis*), mid-day (*beet*), evening (*kosgoleny*), season (*iwoot* = wet, *telelo* = dry), or related to specific ceremonies (*tumdo*). Keiyo education requires that a comprehensive curriculum be learned including language (*kutit*), beliefs (*kabwonuut*), proverbs (*kalewenuut*), games (*urerioshiek*), story telling (*keemwa atindon*), science (*kanetushiekab emeet* = teachings of the world), agriculture (*rokondab mbar*), mathematics (*ng'alekab metit*), and informal teaching of children (*keneet leguk*) in regard to their societal and individual tasks and responsibilities.

In Keiyo culture, although there was formal knowledge transfer to children (*tumdab lagok*), the most emphasized formal education occurs as a part of initiation from adolescence into adulthood (*kaetun*), a period that traditionally lasted several years (*tumdab torusiek* = learners or adolescents bridge to adulthood). Highly regarded individuals are chosen as the teachers (*motiren*) and a distinction is made between male (*kanetindetab weriik*) and female (*kanetindetab tibiik*) teachers. Learning in either informal or formal contexts can occur through watching (*keer*) or demonstration (*keboor*), participatory modeling (*keero* *keboisiei* = you watch me while we work) or apprenticeship (*kerub keldo*), investigation (*kekit*), or teaching one's self (*inetgei*). Assessment of learning and understanding is highly contextual. Tests (*tiemut*) may result in success (*sulda*) because of either effort (*muukte*) or luck (*bor*). A mistake (*leel*) may lead to failure (*iput*).

Keiyo language includes propositional concepts used in probability-based problem solving. There is certainty (*imanit*), almost (*katait*), likely (*aaoksei*), not likely (*maaoksei*); and impossible (*memukaksei*) or null (*buch*). Time can be of the distant past (*ain*), the near past (*omut*), present (*ra*), the near future (*kaaron*), and the distant future (*tuun*). There also exists contextual relativity as to space and time: *nyi, anan nyi* (this, or this) versus *nyi, anan nyin* (this, or that); and contextual prefixes that begin conditional statements, *Ngi* ..., *i* ... (If, then).

Problem Solving in Traditional Cattle Raiding

Understanding the problem. The initial problem or cause for considering a cattle raid would either be a shortage of food (long term drought) or a need to increase the number of cattle following disease (e.g., Rift Valley Fever, see Linthicum et al., 1999). However, obtaining cattle for dowry in families with a high ratio of males to females was also a reason to raid since a dowry is given to the bride's parents. Extensive consensus building was required prior to calling a meeting to initiate development of raiding plans.

> There was famine [1.1.1] ... people of this area gathered together to talk for the purpose of deciding when they would travel [1.1.2] ... war at the time concerned competition for ownership of cattle. There wasn't anything else at stake, just, livestock [1.1.3] ... then *Murenik* were selected, but only Murenik who have not broken cultural morals [1.2.1]. Those people who have broken cultural morals are not allowed to lead the raiding expedition [1.2.1]. No! No! No.

Devising a plan. Complex mixed strategies were used for the preparation and conduction of successful cattle raids. Planning was initiated through clan/group consensus. Elders selected groups of 6-10 warriors (*Murenik*) based on personal attributes such as speed, dependability, experience, past raiding success, and ability to create comprehensive raiding strategies. Numerous groups of scouts (*Segeik*) would secretly travel on independent reconnaissance missions into neighboring ethnic group's territories:

> Women prepared crust, because there was no food, maize had not arrived, No, no, no. Only finger millet and sorghum. Scouts do not

> show themselves to the enemy, they hide in the bushes. What to eat, only the ugali crust powder. Of course, you know where to find water, so you take the powder and drink water ... {2.1.1] people who went in front who were called scouts (*Segeik*) ... [2.1.3] they will go and survey to see where the cattle, herders/enemies, are located. Then, they come back, and upon arrival, they report on what happened on the scouting expedition [2.1.4].

Variables considered for effectively scouting and raiding particular sites included: number and quality of cattle, days of travel involved, perceived strengths in offense/weaknesses in defense, overall site vulnerability, variable routes for escape, access to water for the journey home, distance home, time of year/month/day, and the number of sites that might be included in a raid. Additional concerns included potential encounters with known herds of elephant, buffalo, and lion prides. Following reconnaissance, the clan would again meet and discuss possible events, options and outcomes prior to making a decision for a raid. Generally, a raid would include several sites, be initiated at night under a full moon, and conducted in the dry season when tracks could easily be covered:

> The best time to launch a raid was in the dry season when you could easily cover tracks. The way you would bring the cattle back would not be in the direction you arrived. A full moon would allow you to see where everyone was and to see if the raid was succeeding. We would know where the lions and elephants might be ... and water for the cattle to drink [2.1.3, 2.1.4].

Carrying out the plan. Captured cattle would rapidly be driven by the fastest warriors in a predetermined direction, but not necessarily the most direct route home. Slower, but well armed warriors (*Oldim*) would be responsible for rear guard and covering tracks:

> When they arrive at the location, they would take separate paths [3.1.1] ... from strategic sites, they would raid *beutab tuga* to get the cattle. The *Segeik* drive the cattle, after they get them out of the *beutab tuga* ... but there are some who follow from behind, the guard, the *Oldim*, prevent the enemy from coming after the cattle. In the meantime, others drive the cattle away as quickly as possible. The rest, *Oldim*, return slowly, with their arms, heavily armed, yes, bow and arrow, spears, and knives [3.1.1].

Examination to determine if the solution is a successful result. Following a successful raid, cattle would be equitably distributed among clan members, but individual cattle could be selected for particular genetic traits. Furthermore, each clan member would selectively distribute his cattle to other *beutab* tuga (homestead with cattle) for breeding and so that raiding or disease at any one *beutab tuga* could not result in the loss of one's total herd. A person of high regard was one who historically was able to breed and provide safe care for many cattle.

> When the cattle were brought back ... we would look at them for their health, color and if they were bulls or cows [4.1.1]... then decisions would be made as to who would get which cattle [4.1.2], we tried to be fair and consider peoples needs [4.1.3].

Kechui

A Mathematics Game Based on Traditional Cattle Raiding

Kechui is a simulation cattle raiding game played in a 4 x 4 matrix by making 16 holes in the ground. The game is popular and spontaneously played by children outside of school. Each player's side consists of eight (2 x 4) holes (*beutab tuga*) and represents an ethnic group of cattle raisers (Figure 3). Unripe green and mature yellow round fruits (3-4 cm diameter) of a small perennial spiny shrub *lobotwa* (Sodom apple – *Solanum incanum*, L., Agnew, 1974) are used as counters representing cattle. The shrub grows well in grazed East African grasslands and produces numerous berries almost continuously from one wet season to the next making it a readily available fruit. In addition, the fruits contain toxic solanine compounds (Verdcourt & Trump, 1969) so animals do not consume them.

Each player places an agreed upon, but equal number (usually 4), of Sodom Apple – Solanum incanum fruits (cattle) in each beutab tuga. Consequently, each player begins with as many as 32 cattle. In the outer row, in one corner, and usually, at diagonal ends of the matrix a home beutab tuga is chosen. This designated beutab tuga is an area safe from any raiding. Thus, each time a player passes over this site, and drops an animal, one of the cattle becomes safe.

Either player may begin the game, it may be by consensus or by one player guessing the other's hand that holds an object. The game consists of rounds, subrounds, and moves, respectively. Each player's turn is a complete round. A game's subrounds may be in one direction only (clockwise or counter-clockwise) around the matrix or consist of changes in direction. If a game allows change of direction, direction change is allowed at the beginning of a round, when the last animal in hand is dropped, or after a cattle raid takes place. When play is in one direction only, each turn or round includes only one subround. But, in a game that allows change in direction, several subrounds may occur, that is, every time a player makes a change in direction. Change in direction becomes a randomized event because it may be invoked at the discretion of a player. Direction may not be changed within a subround. A move is considered to take place every time a player passes "through" a beutab tuga. Before a game, player's agree whether to use either one direction only or, if change in direction is used when it can be invoked. A player may initiate the first move of a round in any beutab tuga, but only on his or her ethnic groups' side. At the end of a round, or series of subrounds, it becomes the other player's turn.

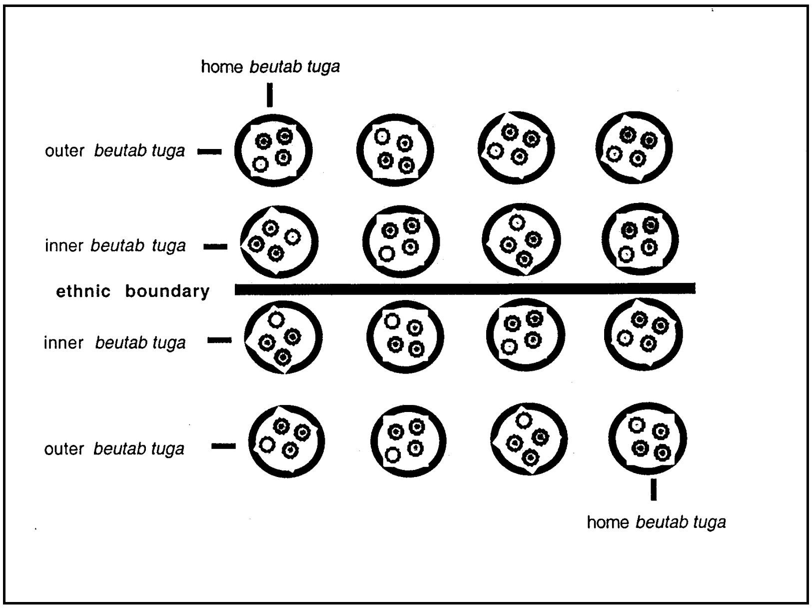

Figure 3. The game of Kechui is played on a 4 x 4 matrix of holes. A player's side consists of eight *beutab tuga* representing one ethnic group of cattle raisers. Each player or side places an agreed upon and equal number (usually four) of Sodom Apples (cattle) in each hole. A home beutab tuga is usually chosen diagonal to the opponent. The goal is to not only get all your ethnic group's cattle into your home beutab tuga, but to raid the neighboring ethnic group's cattle as well.

The game's procedural rules for play follow:

Opening a Round

1. The game begins with one player removing all the cattle from any chosen hole (beutab tuga).
2. The player then begins placing a single animal in each hole passed over.

Moves and Raiding

1. If any cattle are present in the hole at which the last animal in hand is dropped, the player picks up all those animals, continues playing, and leaves that beutab tuga without cattle.
2. If, during a series of moves, the last animal dropped is placed in an inner row the player is able to raid the opponent's adjacent two opposing holes of the inner and outer rows, providing at least one animal is present in the adjacent inner hole, and continues playing. However, if cattle are present only in the hole of the opponent's outer row those cattle may not be raided (they are considered "too deep in the opposing side's territory for conducting a successful raid"). Any cattle in the adjacent beutab tuga of the inner row may be raided even though no cattle are present in the outer beutab tuga. A successful raid consists of picking up all of the opponent's cattle found in the beutab tuga raided. After a raid takes place, the player returns to her or his side and continues play by dropping cattle, but this time begins in a beutab tuga immediately next to the hole where the last animal was dropped prior to the raid. Thus, one animal is left in the beutab tuga from where the raid was launched.
3. A player's designated hole for the home beutab tuga in the outer row is an exception to raiding. It can not be raided. In this case, if a player is able to conduct a raid only the cattle in the beutab tuga of the inner row may be taken.
4. Each time a player passes over the home beutab tuga an individual animal is dropped and consequently, placed in a location safe from raiding.

Ending a Round

1. If, when the last animal in hand is dropped in a beutab tuga in the outer row and there are no other cattle present, that individual's round of play is stopped.

2. If, when the last animal in hand is dropped into a beutab tuga in the inner row and there are neither cattle present in that hole nor cattle present in the opponent's adjacent hole (no raid can take place), that individual's round of play is stopped.
3. If, when the last animal dropped is in the home beutab tuga the round of play is stopped, as it is considered not in the player's interest to remove cattle from that site (traditionally the most well guarded beutab tuga in the territory).
4. Occasionally, if a player thinks it may serve her or his long term interest, such as at the beginning of a round and usually early in the game, cattle may be taken from the home beutab tuga, if it can potentially result in a substantial raid and the gain appears to outweigh the loss.

Ending a Game and Victory

1. A player wins when all of the opponent's cattle have been successfully raided. Or,
2. If one player can not place more than one animal in a hole (excepting the home beutab tuga, thus preventing continued moves on her or his part, the game is ended.
3. All cattle on each side are counted and the player with the highest number wins.

Problem Solving in Playing Kechui

Eight games were played by the sixteen students studied. Time used in playing the games averaged 30 minutes and ranged between 45 minutes and 12 minutes. The highest number of subrounds used in a game won was 120, whereas the lowest number used by a loser was 42 subrounds. The highest difference between a winner-loser was 48 cattle (56 winner, 8 loser) and the lowest difference was eight cattle. In some games, participants by consensus, would allow play in one direction only and in other games, would allow change of direction after each subround. Students stated that they regularly vary this rule depending upon one's past success, as a way to think about alternative strategies to outplay opponents and as a way to increase more cattle in the home beutab tuga. To add variation, they also randomly changed the designated location of the safe beutab tuga in the outer row in games played. Occasionally, if it were early in a game and seen as a crucial step to winning a game, a player would begin a round by removing cattle from their safe beutab tuga. Additionally, sometimes the safe beutab tuga would not be announced by a player until by chance one found a particular location to have a high number of cattle, especially after the first round. Finally, one variation made with respect to determining the winner was, rather than tallying all the cattle on each side to count, only those cattle considered safe in the home beutab tuga were allowed to be counted.

Understanding the problem. At the beginning of a game players started at any one of the holes, but provided reasons for their choice:

> I started here and moved in this direction because my first interest is in getting as many cattle as I can into the safe beutab tuga [1.1.2].
>
> I started here because from experience, I knew I would be able to raid during this round [1.1.3].

Devising a plan. Prior to each round, a player surveyed the existing number of cattle in each hole of the inside and outside rows, chose a starting beutab tuga and counted or made estimates in each direction to determine which series of subrounds would provide the most benefit. Initially, this strategy is exceedingly complex and requires concentration and time because the number of possible changes of direction in the first rounds are very high. As the number of cattle available for moves in a round or subround decreases the options for direction and moves also decrease. However, as the number of cattle obtained in a raid dwindles, decisions for a round's moves inversely be come more critical with regard to a player's chance of winning.

At times, a player would calculate that a round might leave several cattle vulnerable, but either the opponent would not be able to reach those cattle during her or his round, or the number of cattle left would not exceed the subsequent number of potential cattle that could be raided from the opponent during the round. The gains exceeded potential loses. Each player also considered a likely starting point for the opponent's next round. Thus, the advantages and disadvantages of her or his choice of moves would include "Will raiding on my part leave too many of my own cattle vulnerable?" Subsequently, a player might concentrate on moving as many cattle as possible into her or his own home beutab tuga during a round:

> I cannot start here, because I want to start there, so that I can get directly at the opponent's cows [2.1.4].
>
> You know, I am escaping because this person will take so many ... if my cattle are in the inside row of holes ... so I want to go outside. I am trying to escape from the inside holes, to distribute

> the *tugab labot* to the outside so the opponent cannot get a chance to take everything from this row [2.1.4].
>
> My plan is to get the cows in the safe beutab tuga [2.2.3].
>
> I started here because I counted, 1, 2, 3 holes and I would end in hole where I could collect many cows [2.1.4].
>
> I counted 1, 2, 3, 4 holes, so if I started here, I would end up collecting 2 cows. That would prevent the other player from getting cows [2.1.4].

Carrying out the plan. As players made and completed rounds or subrounds, they became more aware of the outcomes for possible choices. Problem became more refined, especially if the initial round plan was based on estimation, rather than counting.

> I counted that I had four cows and I wanted to get to the safe beutab tuga [3.2.2].
>
> I wanted to stop here so that I could get the opponent's eight cows in these two holes [3.2.2].

Examination to determine if the solution is a successful result. At the completion of each round or subround and the game, a player evaluated the consequences of moves made:

> When I made my move I went past where I thought I would end, one space beyond [4.1.2]
>
> I was not careful enough. My estimates were not very good [4.1.2].
>
> I did not play well. I failed because I have only 8 cows [4.2.1].
>
> My opponent won as you can see. She has many cows [4.2.2]. I have to try and use better strategies so that I can win next time. I have to make sure I count before I make a move [4.2.3]. I have to put my cows on the outside so that they are out of reach for the opponent.

Students' Problem Solving in Transmission Genetics

An analysis of students' interviews and drawings indicate that they modeled their textbook demonstrations for crosses, using lines to connect parents and progeny. Students, when asked, were unable to make any statements that reflected an understanding of probability related to the meaning of their lines connecting gametes or genotypes or ratios for progeny phenotypes. Furthermore, students did not use tree diagrams or matrixes (Punnett squares) as advocated in the Kenyan syllabi (Kenya National Examinations Council – KNEC, 2000) and by geneticists (Russell, 1996; Futuyma, 1998). Students attempted to solve dynamic probability-based problems generated by GCK as textbook problems. Furthermore, students were unable to account for any GCK phenotype numbers ratios resulting from chance and deviating from standard stereotyped textbook ratios. For example, if the outcome of a GCK cross for two individuals could result in two possible phenotypes (monohybrid complete dominance inheritance), one occurring as a 1:1 ratio and the other as a 3:1 ratio, students were not able to distinguish or explain intermediate outcomes that were a result of chance occurrence, such as a 2:1 ratio. A similar problem occurred for the students if, in a codominance problem, phenotypes deviated from the textbook model of 1:2:1. Nevertheless, most continued to make additional crosses. But, without understanding the nature of the problem or being able to develop a strategy or hypothesis, the accumulation of data overwhelmed them. They would reluctantly concede that the problem was now unsolvable, even when otherwise meaningful data was, in fact, present.

What do Cattle Raiding, Kechui, and Genetics Problem Solving Have in Common?

In problem solving, there are many large scale strategies that are common across problem types, although not all strategies may be required for an individual problem. Cattle raiding, Kechui, and transmission genetics problem solving share Polya's (1971) steps (four) and Thomson's (1993) strategy types (10) and general strategies (24) . They also share several attributes (Table 1) from which, a case might be made that Kechui can serve as a culturally relevant and useful conceptual analogical model (see Glynn et al., 1995) for introducing transmission genetics. In this context, the probabilistic "phenotypic" outcomes (number of cattle per hole) resulting from a round of play in Kechui are more closely tied to real world and computer generated simulations for genetic problems, than are stereotyped tree diagrams and Punnett square pedigree ratios presented in textbook descriptions and problems.

Naturally, as one looks in close detail at any individual problem, the strategies and knowledge required for creating a solution ultimately become tightly connected to context and content/domain specific knowledge. Consequently, caveats must be heeded when using analogies and recognizing limits of transferability across problem types. For example, in their work with the computer-based genetics program GenScope, Horwitz (1999) have found that students often fail to transfer knowledge gained on the computer to performance on paper-and-pencil assessments. In contrast, the students in this study were unable to make a connection in going from textbook to computer generated genetics problems. Obviously, more research is needed to understand the problematic issues surrounding transferability and analogy use across problem types.

Table 1. *A Comparison of the Attributes for Problem Solving in Cattle Raiding, Kechui, and Transmission Genetics*

	Cattle Raiding	Kechui	GCK Problems	Genetics
Problem Type	Dynamic	Dynamic	Dynamic	Dynamic
Problem	Real World	Simulation	Simulation	Real World
Environment Strategy Types	Mixed	Mixed	Mixed	Mixed
Objects	Cattle	Fruit	Cattle & Pea Seeds	Cattle & Pea Seeds
Object Colors	Black, Red, Roan, White	Green, Yellow	Cattle: Red, Roan, White; Seeds: Green, Yellow	Cattle: Red, Roan, White; Seeds: Green, Yellow
Measurement	Quali- tative, Quanti- tative	Quantit- ative	Qualitative Quantitative	Qualit- ative Quantit- ative
Probability	Ordinal	Ordinal	Nominal, Interval	Nominal, Interval
Criteria Decision Basis	Nominal Ordinal Patterns Absent	Nominal Patterns	Nominal, Patterns as Distinct Ratios; Statistical	Nominal, Patterns as Distinct Ratios; Statistical

Discussion and Implications

Mazrui (1986) has characterized Africa as sharing a triple heritage: its endogenous heritage and two major exogenous influences, Islam and Westernization. In the 17th century, as Western natural philosophy was being established as a way of understanding the natural world, Francis Bacon wrote that the most noble ambition for man was "to establish and extend the power and dominion of the human race over the universe .... We cannot command nature except by obeying her and understanding her" (cited by Aikenhead, 1994). During the 18th century, in the quest for access, exploitation, and control of natural resources in Africa, western European Nations' felt it necessary that global "power and dominion" include indigenous peoples (Mazrui, 1986). Consequently, indigenous African beliefs, values, and identities were relegated to a status of existing as primitive antiquities needing documentation, and then, followed by replacement. Replacement has had two natural allies in the guise of missionaries: indigenous metaphysical beliefs were challenged through religious education (Mbiti, 1969; p'Bitek, 1971) and epistemological beliefs were addressed via secular education (Bogonko, 1992; Njoroge & Bennaars, 1994; Shiundu & Omulando, 1992; Tsuma, 1998). A recent challenge to this mode of change is the concept of autonomous acculturation introduced by Taylor and Cobern (1998) that tries to answer the question "Whose interests are being served?" (p. 203). Autonomous acculturation brings to science education new perspectives including social justice, cultural differences, diversity, and the promotion of culture-sensitive curricula to prevent "insipid global uniformity" (p. 205). A critical caveat to their views is that prior to adoption, adaptation, or assimilation of any exogenous science education, it is urgent that endogenous science and mathematics education systems be recognized and allowed to firmly establish their legitimate foundations.

Education and Extinction in Africa

Indigenous sports and games. As a legacy of educational colonialism, many of Africa's traditional games and sports have been disappearing as the role of colonization was to prepare indigenous peoples for lifestyles and values counter to traditional practices (Chepyator-Thomson, 1990). In fact, "African games were actually discouraged by the colonial education authorities in favor of ludo, snakes-and-ladders, and similar games of European origin" (Zaslavsky, 1991, p. 131). And, the postcolonial sports identities and pride of many African countries continue to be made via imported sports such as soccer and basketball.

Conversely, the continent's most extolled players are usually exported and leave for lucrative professional careers in Europe and the Americas. Thus, even in post-independence, Africa too, has also been slow to recognize and promote the value or importance of its indigenous games and sports. For example, Kenya promoted its heritage in formal education in the Gachathi Report (1976), a national statement on educational objectives and policies in the statement that: "culture constitutes social organization, traditional technology, language, beliefs, religion and inherited traditions" (pp. 9-10). But the schools' national curricula limits "inherited traditions" to "cultural dances, traditional festivals, and school music festivals" (cited in Shiundu & Omulando, 1992, p. 50) with no mention of games. Furthermore, in the national syllabi for physical education, there is no mention of indigenous games and sports. Organized games and sports, which are promoted for development of skills – physical and mental – are restricted to non-African "validated" activities (Chepyator-Thomson, 1990). In her study of the Keiyo people, she determined that within two generations of 34 games being played by elder males, only nine (26%) are still played by boys. For elder women, of the 27 games they played, 16 (60%) are still played by girls. And, yet where Keiyo and Western game values have been able to intersect, Keiyo males have been able to excel internationally, most notably in distance running. Contrariwise, cultural practices in terms of distance running had a negative impact on its women since running was considered to be counterproductive to a woman's traditional social and cultural responsibilities. Today, because of cultural change and economic incentives, a high number of Keiyo women are also among the world's running elite, with one of the authors, Chepyator-Thomson, being a pioneer.

Indigenous science and mathematics. Historically, as with games and sports, science and technology in Africa has been subjected to a unidirectional flow of development, knowledge, expertise, and promotion. As viewed by Dart and Pradham (1976),

> The attitude and often the intent of western education has been that a 'primitive' or decadent' civilization is to be replaced with a more 'modern' and 'better' one .... It tends to be particularly strong in science teaching, for science teaching is taken to be the one really unique and powerful offering of the western world. (cited in Jegede, 1994, p. 121)

Not surprisingly then, indigenous African science education has received even less attention than games. Within a small community of science education researchers there has been a history of concern with respect to compatibility of Western versus indigenous African science curriculum and learning (e.g., Anamuah-Mensah 1998, Cobern 1996, Black et al., 1998), research methods and student learning through contextualized science experiences (Lubben & Campbell, 1996), and issues concerning second language use (Calloids, Göttelmann-Duret, & Lewin, 1997; Rollnick & Rutherford, 1996; Seddon & Waweru, 1987). But, these studies have been presented in the mode that African cultures can, should, and will conform to western science. However, conform from what? – to what? – and why?

One view of multicultural science is that Western assumptions, models, and relationships (especially concerning the physical world) exist at macro- and micro- levels and scales that now offer unequivocal contributive explanatory frameworks that transcend all cultures (Hodson 1998, Mathews, 1994). Thus, in order to carry on meaningful global dialogue, science language and practices may not necessarily utilize a shared Western understanding. However, many cultures have constructed and daily continue to effectively utilize various traditional educational models and knowledge structures to teach, represent, and exemplify contextual and functionally useful understandings for natural phenomena. Furthermore, some research ecologists (Juma, 1989; Jungerius, 1998), botanists (Dale & Greenway, 1961; Kokwaro, 1976) and ichthyologists (Goldschmidt, 1996) have recognized and rely upon endogenous knowledge systems. Most problematic is that not only much of the world's biota is at risk, but also many cultures – extinction is forever. And, educators are in part, a causal agent of the problem.

From a more enlightening perspective, some components of African quantitative thought and activities that have focused on numeracy have recently been recognized. They have gained an international reputation for their creativity and complexity of work through the research efforts of ethnomathematicians with respect to patterns of geometry and numeracy (see Gerdes, 1995, 1999; Zaslavsky, 1991) and other studies have been able to focus on indigenous games (Chepyator-Thomson, 1990; Zaslavsky, 1991). Haggerty (1964) argues that one African game *"Kalah,* is the best all round [numeracy] teaching aid" (p. 328) because:

> In addition to its value as a diversion and as a means of developing the intuitive abilities so important to problem solving, there is another outcome equally valuable, This outcome is the recognition of the close identification of the game throughout the history of civilization with the development of systems of numeration and the concept and ideas of number. (p. 330)

The endogenous emergence of solutions to Africa's problems. The purpose of this study was to document an indigenous Keiyo matrix game of probability that is being maintained outside of the Kenyan mathematics or science national curricula. There may be two important reasons for the lack of demise of some indigenous African games. One reason may be because they are so culturally valued, challenging, or cherished that they have remained extant and practiced outside formal educational settings. Second, Kechui relies on the use of local and readily available natural materials allowing spontaneous play by males and females in present day Kenya. Cattle are highly valued in Keiyo culture. Kechui is a challenging indigenous numeracy Keiyo game based on mixed strategies analogously used in cattle raiding. In addition, the deconstruction of game plans for cattle raiding reveal that females and males' functions were equally valued and present day youngsters equally take part in playing the game albeit without present day involvement of cattle raiding. This has largely been curtailed in modern day Kenya. Nonetheless, ethnicity as fostered through continued cultural practices, such as initiation and associated customary activities, remain very strong in Keiyo culture, and in Kenya as a whole. For the most part, people view these practices as positive aspects of their ethnic group.

Whereas Keiyo students used and demonstrated an understanding for concepts of probability in Keiyo while playing the matrix game of Kechui, this knowledge was not apparent in solving transmission genetics problems. Language may be one factor limiting either knowledge transfer or demonstration of an equivalent mathematics concept in English. Choice of analogical models used to introduce concepts of probability may be another. Kenya's national mathematics (Form III) and biology (Form IV) syllabi recommend coin and die tossing and counting seeds in pods to introduce probability (KIE, 1992; KNEC, 2000) with no reference to contextual cultural experiences. Textbook presentations and problems also appear to limit or impede students' understanding of events based on probability because of the problems modeled (Thomson, 2000).

Promoting indigenous educational systems is not without its caveats. The academy of the dominant cultures determine educational equivalency standards and, thus, control transferability. Ironically, often it is these very researchers whose professional livelihood depends upon indigenous cultures and peoples who deny the credibility of knowledge emanating from these cultures. These researchers further separate themselves claiming the intellectual (copyrights), material (patents), remuneration (monetary) rights, and credit (authorship) that rightfully belong to indigenous peoples (Cox, 2000; Kimani, 2000). In cogently arguing for curriculum reform building on traditional mathematics, Gerdes (1995) reflects using the African proverb "When lost, it's better to return to a familiar point before rushing on" (p. 6). His concern is that Africa is continually challenged to adopt curriculum transplantation, but each of the "new mathematics" curricula has usually ended up, and ironically, failing in the country of origin.

There may be a growing emergence of thought that endogenous African cultures have credible knowledge to contribute to human understanding beyond the oft heard proverb "it takes a village to raise a child." There exists a plethora of initiatives and a myriad of alternative curricula that country's are all too willing to export as development or aid packages without weighing or comprehending all of the consequences. But, perhaps now is the time to be more attentive to the important African endogenous educational systems for guiding reform. However, as one Keiyo proverb states "you do not kick a cow when it is giving milk." Consequently, if the funding for endogenous reform must come through external donor agencies and organizations via researched-based initiatives, a liberative perspective should be embedded in the assistance. This, along with those Kenyan governmental agencies charged with curriculum reform may then be more responsive to the current call for richer indigenization with respect to the aims of education.

Optimistic as the authors are on the documentation and preservation of indigenous knowledge, they would be remiss without mentioning resistance encountered from neo-colonialism as it influences education, particularly in Kenya. Then, the question becomes how best to decolonize educational infrastructures? Perhaps as Mazrui (1990) suggests, strategies of de-colonization may best be realized through a "strategy of indigenization" (p. 80) which aims at putting African consciousness at the center as opposed to being at the periphery, a practice in vogue during the colonial period in Kenya. Ideally, this would be the best case strategy but with the achievement of independence in Kenya, the Western-educated elite took over the state education apparatus along with British subjects who remained following independence, making it impossible to de-colonize the education system. For instance, the Gikuyus in Kenya had "high investment in education and had been able to establish [themselves] as the dominant hegemonic group" (Maughan-Brown, 1985) following independence and hence currently command a large share of economic and educational state infrastructures in the country. Hence, this group along with other western educated elite will not see the strategy of indigenization as viable. But this study, and others along similar lines of inquiry, may assist researchers and scholars in and outside the country to see the benefits of indigenous education. In this regard, then, indigenous games and dances may promote and preserve cognitive and social strategies of existence that result in far more important implications with respect to living in a global village. Indeed, the benefits of indigenous educational systems are enormous provided scholars and researchers, in equal partnership with indigenous people, work to document and preserve knowledge in our global communities. At some time in Keiyo history someone realized that cattle raiding could be represented and used as an abstract simulation activity for learning mathematics. The game of Kechui helps us to deconstruct Keiyo history thus, making us aware of the past as it happened and provides us with a way to "sharpen our minds" in light of the present day educational system and economic infrastructure in Kenya. Subsequently, indigenous knowledge systems may inform us of the past, challenge taken-for-granted exogenous theoretical frameworks, and offer new perspectives for changes in education.

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