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Design principles for creating locally-rooted national science and mathematics curricula in Timor-Leste

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Abstract

This paper articulates and illustrates design principles that guided the development of a set of hands-on teaching activities for the national science and mathematics curricula at junior-high and high-school level education in Timor-Leste, a small, low-income nation in Southeast Asia. A partnership between a university, an international science educator (the first author), local teachers and students engaged in a series of collaboratively created activities to make a set of learning resources to support student learning, teacher development, and subsequent curriculum development. The design principles included: seeking locally-rooted topics, supporting experiential learning, and ensuring sustainable use and delivery of instructional materials. These design principles guide the enactment of instructional practices to support culturally relevant learning situated in problems of everyday life. Using three examples of design activities that emerged from Timor-Leste's culture and environment, we demonstrate the high utility that these design principles have in sustaining further education and development in Timor-Leste, as well as creating and supporting inquiry-driven learning environments more generally.

Key words: *science, mathematics, design principles, design activities, cross-curricular activities*

Introduction

From 1975 to 1999, Timor was under violent military occupation by the Indonesians, and most education was overseen and operated by the occupiers (Arenas, 1998; Hill, 2002). Indonesian teachers in Timor as a whole had little motivation to see their students make progress and succeed. In 1999 after a United Nations-administered referendum demonstrated clearly the will of the people, the UN governed Timor until independence was formally declared on May 20, 2002. (In 1999 schools were disrupted for at least one year while the referendum on independence was prepared and carried out. The subsequent destruction took place during Indonesia's departure.) The violence in 1999 resulting in a severely damaged

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infrastructure, 80% of schools destroyed, and thousands of civilians displaced, resulting from independence being voted in against the wishes of the rulers, the country has had to rebuild itself including the formation of new education systems necessary for a functioning country. Experienced teachers were primarily Indonesian and nearly all of them left Timor-Leste and returned to their homeland leaving a vast shortage of qualified teachers. Still today many under-qualified teachers continue to teach children, especially in isolated rural areas where no better can be found. In addition to the shortage of qualified science teachers, most current education leaders also possessed limited experience in education leadership, professional development, and administration. The education landscape continues to change and education leaders attempt to plan for long-term development (Hill, 2005).

In such a climate, how does a country create a strong, coherent national science and mathematics curriculum and teacher development program and continue to grow its educational capacity in this area given limited resources, expertise, and infrastructure? It is in this broader political, cultural, geographic context that the first set of learning prototypes, science teaching resources, and instructional design principles were developed for and by teachers and students in Timor-Leste.

Framework and design principles for educational development

In 2009, around sixty local students from the national university[†], eight teachers and the author, an international consultant and science educator, created a multimedia Encyclopaedia of 83 science and mathematics topics from the daily life and experience of the Timorese. This multimedia Encyclopaedia included reference information (e.g., activity instructions, background science, explanations) and short videos of simple hands-on activities that teachers could carry out in schools using locally-found materials to illuminate these topics. For example, marbles are an ever-present artefact used to play different games among children in Timor. One teaching video shows two teachers carrying out a simple energy and momentum experiment by dropping various marbles and measuring the rebound height with a meter stick placed against the classroom wall. This simple quantitative physics experiment helped to make visible the physics behind the game.

Taken as a whole, the Encyclopaedia was designed to provide a starting point for the development of new curricula as well as serve as a teacher's reference resource. The Encyclopaedia served also as a tool for teacher development through a process of participatory design (Schuler & Namioka, 1993). Different stakeholders create together to ensure the work results in a usable end product that is responsive to cultural, emotional, and practical needs. Viewed from a learning and development perspective, the multimedia Encyclopaedia provided a shared focal point and a jointly created artefact to support collaborative knowledge building among members to build a professional learning community[‡]. Knowledge building draws on the collective intelligence of a group engaged in investigating, theorizing, critiquing, making, reflecting, and revising in order to progressively advance a community's shared theories, knowledge, and practices (Scardalalia & Bereiter,

[†] The participating students were enrolled in various departments of the National University of Timor Loro-sae's Faculty of the Sciences of Education. This is Timor's only public preparation institution for future pre-secondary and secondary teachers.

[‡] While not a curriculum per se, the Encyclopaedia was distributed to Timor's teachers, and in the following year, SESIM provided training for a group of pre-secondary and secondary teachers on how to use the Encyclopaedia to teach experiential, locally-based lessons.

1994). In a professional learning community, participants have shared values and a vision, take collective responsibility for each other's learning, engage in reflective inquiry, and work collaboratively (Stoll, Bolam, McMahon, Wallace, & Thomas, 2006; Vescio, Ross, & Adams, 2008.) The focus is not on the individual teacher's professional learning, but professional learning within a community context. Using this community-based participatory design approach to curriculum development, the teachers were more likely to both give recognition and take ownership (and pride) in the lessons developed in the resulting knowledge resource.

The lead science educator (and first author) took the role of a facilitator to model the process of inventing activities and bring focus to local topics with high potential for the Encyclopaedia. While he did most of the writing for the Encyclopaedia, the students themselves conceived, developed and tested the activities. The Timor teachers edited both the content and presentation of materials. He noted time and again the teachers' astonishment at realizing the richness of science and mathematics content in familiar everyday phenomena and artefacts. These teachers then displayed something like an evangelistic desire to show others what they had found in front of their noses.

One might ask how a group of university students and teachers creates robust national curricula when there is limited formal science expertise and knowledge of pedagogy among the people. A common tendency is to assume a deficit model and consequently impose fully published science and math curricula from another nation that has been found to promote achievement. Here, intellectual resources viewed as "funds of knowledge" (Moll & González, 2004) from the Timorese were used to promote learning and engagement. The collective Timorese experience served as the context for generating the activities in the Encyclopaedia. The Timorese brought knowledge from their craft skills, common observation of earth and life systems, and every-day practices centred on work and the improvement of life through greater understanding of the world around themselves. Similar to curricular standards established for education in sustainable development (see Venkataramana, 2009), common questions were often related to engineering a design that required learning and applying knowledge of mathematics and science to solve community-oriented and culturally relevant problems. The driving questions were timeless ones from real life, such as, "How can we farm more productively?", "How can I make a traditional gun to shoot birds more effectively?", "How might we weave a beautiful new rice dumpling katupa for the feast?", and "How can my family make a house using the materials that we already have here?". Rather than pose questions that would set the stage and atmosphere for competition resulting in a single winner, these questions invited collaborative inquiry and community-based design towards development and improvement. The contents of the Encyclopaedia are based on these kinds of questions as well as the philosophy that people from any locale learn and do, and have done science and mathematics naturally through their own experiences since time immemorial (George & Lubben, 2002). The custom of working in groups when solving an everyday design challenge was already part of their everyday practice. The facilitator's instructional approach in recognizing, respecting, and bringing to bear the local knowledge and practices of Timorese was essential in making progress.

Inquiry-based science instruction that actively engages students in the learning process including hands-on engagement with science phenomena and an emphasis on student responsibility are more likely to increase conceptual understanding (Anderson, 2002; Minner, Levy, & Century, 2010.) Thus, the inclusion of instruction that fosters scientific inquiry skills and engagement in scientific thinking practices may serve as a useful for formal science education to pose investigable questions, propose multiple alternative explanations, and collect data to verify and support one's conclusions (NSF, 1999; NRC, 2012). In contrast to using magic or religion, science and mathematical reasoning through a process of guided inquiry often leads Timorese to useful effective, repeatable results while recognizing that they may have different epistemic criteria for reaching conclusions. This kind of reasoning can be readily found in the development of traditional agriculture techniques, architecture, hunting and fishing methods, and the making of many indigenous health remedies. Thus, when students can use both plausibility and empirical evidence in scientific thinking and be led down the same paths their ancestors trod to discover for themselves how their world works, the result is a powerfully motivating and engaging set of activities that can be included in a national curriculum. This stance on science learning is consistent with learning and development viewed as cultural processes that embrace and use community-derived knowledge as an asset to learning academic science content (Bang & Medin, 2010; Nasir et al., 2006; Rogoff, 2003).

During the process of creating this Encyclopaedia, the teachers formalized their meetings to form an emerging professional learning community called SESIM, an acronym from Tetum, Timor's lingua franca, for "Centre for the Study of Science and Mathematics." SESIM's mission was to promote and improve science and mathematics education in Timor. Since the launch of the Encyclopaedia in late 2009, SESIM has continued to develop and write new topics for a second volume, while carrying out periodic trainings of teachers and students, and attempting to find an institutional home for itself within Timor's educational establishment. All this action was toward advancing its mission as the first Timorese science and mathematics curriculum-development and teacher-training organization.

Example activities

In this section we describe in detail three cross-curricular activities from the Encyclopaedia, then show how the core principles are articulated within each topic and how they were derived from the key design principles: locally-rooted, experiential, and locally sustainable. Through these three principles, we hope to illustrate how a community-designed curriculum approach can produce both robust curricula and culturally relevant learning environments for both learners and teachers. The three activities are summarized in Table 1.

Activity 1: Chicken foot and arm model

The human hand is both a simple machine as well as a complex part of the human body. In this "explore, model, and compare" activity, students first explore the foot of a chicken and then later transfer and apply their knowledge to build a physical model of hand/arm. Because most Timorese own chickens, the feet are easily accessible and not considered an extravagance nor a delicacy. In small groups, a chicken's foot is dissected using razor blades and pins; skin, muscles, bones, ligaments and tendons are identified and explored. While students hold the chicken foot, they are invited to pull on the tendon and witness the resulting movement. After this exploration, the students are given a challenge to construct a physical model that behaves like their own arm using simple materials. After each group constructs their arm model, they go on to examine their own arm and compare the models to their own arms (Figure 1).

Table 1. Summary of three activities illustrating the design principles

Activity Name	Description	Materials Used	Disciplines + Topics, Big Ideas	Principle #1 Locally Rooted	Principle #2 Experiential	Principle #3 Locally sustainable
Chicken foot and Arm model	A chicken's foot is dissected; muscles, bones, ligaments and tendons are identified and explored. An anatomically correct model of the human arm is built.	Chicken feet, razor blades, kabob sticks, rubber bands, string and tape	**Biology**: anatomy, kinesiology, structure and function of muscles, bones, joints **Physics**: force and motion, simple machines, levers	Most Timorese own chickens, familiar with body structure. Feet are easily accessible, as are materials for constructing model.	Each small group will touch the chicken foot, pull on the tendon, witness the resulting movement. Each will construct a model that behaves like their own arm, then examine their arm.	Activity is easily possible for every student in Timor. Extremely low cost.
Basketry with rhombus weave	Various types of baskets that employ the 60º/30º rhombus weave are analyzed. Simple versions are weaved.	Common baskets from students' homes, pencils, palm leaves	**Mathematics**: geometry, angles, shapes, patterns, transformations, area and volume, factors and factorization, size and scale	All families in Timor have and use these baskets on a daily basis. Most families have members that can weave them, most often women elders, usually without formal education.	Baskets are in hands being scrutinized for mathematics. Each student personally uncovers submerged mathematical concepts with guidance by teacher. Many major concepts from canon are discovered, observed.	Basket materials are available for free from the jungle; students can each bring baskets to school for analysis. On-going investigation is easily facilitated.
Leaf tensile testing	Four types of palm leaves are tested for tensile strength using simple gravitational arrangement.	Palm leaves, cargo basket from students' homes, water bottles, rocks,	**Engineering and Physics**: data taking, data analysis force, gravity, tension, density, weight and mass, **Biology**: structure of plants and plant tissue, cells, moisture content,	Name of one of these palms is synonymous with "string;" its leaves are routinely used for tying things such as animals and roofing. The strength of this palm leaf is well-known, so to make a methodical test to compare the strength of the others is illuminating.	"Common knowledge" (hypothesis) is put to the test with the scientific method in front of all to witness. Hard data is taken in the course of a legitimate, student-conducted experiment.	Lab activity is completely cost free. No special, foreign materials are necessary. Even weight can be calculated by measuring volume of water if a scale is not available.

Figure 1. Students demonstrates a model of our arm's bones, muscles and tendons. It is constructed from kabob sticks, rubber bands, thread, cardboard, and sticky tape.

This activity was motivated in response to students' curiosity and interest in body structure. Upon seeing this interest, the author introduced dissection and the model which he had used for teaching in the US. Immediately the activity had to be "Timorized" both the dissection and the model activities had to be carried out successfully with common, low cost, and locally available materials. In this activity, the materials used – chicken feet, kabob sticks, thread and rubber bands– are locally available and sustainable materials. The activity is also locally rooted because most Timorese are intimately familiar with the body structure and movements of chickens. Finally, the activity was highly interactive and experiential, giving students direct experience in model building using simple, easily handled materials that also afford a wide range of configurations for potential designs. This activity also highlights the kinds of scientific thinking practices that are valued in progressive and innovative science education: exploration, inquiry, modelling, question asking, hypothesis generation, comparison, and explanation (NRC, 2012).

Activity 2: Basketry with rhombus weave

Baskets are ubiquitous in all Timor homes. Families use baskets daily for storing and transporting food and other articles, and also for preparing and serving food. Given the tropical climate, leaves of palms, bananas, and other jungle plants provide ready raw materials with which to make baskets and other useful and decorative artefacts. Most families have a member who can weave baskets, most often women elders, many of whom have never attended school. The rhombus weave is a common pattern which builds on a 60º/30º rhombus and equilateral triangles. This weave creates hexagon units and six-pointed stars, and can easily be turned to create sides and corners on a basket.

Students are encouraged to bring baskets to class as a first step in the participation of the learning community. Similar to the chicken foot activity, the activity starts with students making observations on many different types of baskets. Students are asked to focus on baskets with the rhombus weave and analyze the patterns to better understand their structure. Questions emerge with subtle, new observations, followed by more intense observation. Leaves, which are a prevalent natural resource in Timor, may also be brought in and simple versions weaved. Students have the opportunity to not only learn how to investigate baskets, but also take awe in their ancestors' embodied knowledge of mathematics.

One common rhombus-weave basket that holds small sundries or betel nut supplies is called the Mamafatin. This basket is generally decorated geometrically around its circumference with repeating two-dimensional patterns (Figure 2). While patterns may be copied strand for strand, it is impossible to create a new pattern that repeats and matches up seamlessly without understanding the fundamentals of mathematical factors and multipliers (Figure 3). Here, the instructor can use this opportunity to explain factorization while also highlighting the utility of mathematics in understanding objects from everyday life. Complete factorization may be accomplished by using similar baskets having various patterns with the same total number of strands.

Figure 2. A rhombus-weave basket showing the topological complexity this weave makes possible. Students may find stars with less than or greater than six points, and discover how the rhombus is manipulated to make other decorative shapes.

Each student or group of students uncovers submerged mathematical concepts with guidance by teacher. Students discover and articulate many major concepts from the canon. Two other underlying facts that also often emerge are:

- Each basket model was created by a person or group of persons generations ago that manipulated topology with available leaves to invent a key functional artefact for their community.
- Today Timor's women elders hold this sophisticated knowledge that enables the production of these daily essentials.

Figure 3. A Timorese basket present in every household leads students from the mathematics group to work out what every old woman basket weaver knows: how to get the pattern to repeat an integer number of times around the sides of the basket.

Activity 3: Leaf tensile testing

When asked to name the local leaf with the most tensile strength, all Timorese would answer, "tali." This palm, known as Sago in English, is an everyday material and well known for the strength of its leaves as well as the stiffness of its spines and the nutritional value of its trunk. The word "tali" also means string in Tetum and indeed the Sago palm leaves are used directly for tying everything from loads on trucks to water buffalo. The leaf tensile testing is motivated by people's desire to make and use strong rope. However, an unfamiliar practice to the local people would be to quantify this strength, engineer it to be a stronger material, and/or to compare it with other leaves. The teacher frames the activity as a useful method that can help determine and quantify the strength of different tali leaves and other kinds of leaves. This group activity which requires configuring a measurement instrument, testing samples, recording and analyzing primary data is a straightforward activity found in traditional engineering tensile test laboratory exercises, but instead employs locally available materials and does not require a formal laboratory space.

Students gather and bring to the classroom long leaves from the tali and four other similar plants. Ideally each specimen is gathered in both young (green, tender) and older (brown, more brittle) forms. Each leaf is tied in a loop and installed on the tensile testing apparatus: a horizontal bamboo shaft suspended far enough off the ground to enable a basket (likely woven from tali leaves, incidentally) to be dangled beneath it. Students are asked to find heavy items to fill the baskets. Through the collective creativity of the students, bottles are filled with water, sand, or small rocks, and other heavy items are then placed in the basket one at a time until the leaf breaks (Figure 4). If a standard scale or balance of any kind is available, the total weight (force) is totalled and recorded. If not, the weight of a litre water bottle is taken to be approximately 1kg, and a crude see-saw balance can be used to estimate the weight of bricks and other weights. The activity allows children to make predictions, test their predictions, and see the outcomes, which enables the teacher to illustrate iterative engineering design process and the scientific method. Students are actively invited and accompanied to engage in thinking about the methods of testing and ways to improve upon them. For example, one of the student groups twisted the leaves, but only certain kinds of leaves based on how they were already familiar with the use of these varieties. However, the twisting introduced another variable. This was a fine opportunity for more discussion and reflection on the scientific method, examining our original hypotheses against results. Finally, the instructor uses the data collected from each trial to introduce the concept of evidence from data and a bar chart, providing a purpose, motivation, and an easy way to explain outcomes as well as an opportunity to teach graphing and chart reading.

Figure 4. Students are testing tensile strength on leaves from different species of palm and of different ages. Weight is added to the basket until breakage occurs, and then the weights at which catastrophic failure are added up. Results are then graphed and compared with the students' predictions.

Pedagogical design principles

The three example activities presented here from the Encyclopaedia embody key design principles that the SESIM partnership used to teach science and mathematics concepts grounded in local traditions, familiar objects, and everyday inquiry practices resulting in the development of rich science and mathematics curricular materials especially rooted in non-Western traditions. These principles also inform SESIM's other activities such as teacher development and teacher mentoring. As generalized here, these design principles are relevant for guiding additional community-designed science learning experiences and instructional materials development in the developing world and other resource-constrained communities. Here they are explained in detail:

Design Principle #1: Content, examples and activities must be locally-rooted

In a community that continues to strive to feed and rebuild itself, students and their families have little patience for learning abstractions, theories, and "inert knowledge" (Whitehead, 1929). The concepts focused upon in instruction needed to be both pertinent and relevant to life in Timor, socially, culturally and economically. The concepts we chose for elaboration are based on Timorese' experience, daily, common practices and objects such as those found in cooking or toys or special noteworthy events (e.g., lightning, drought, and earthquakes). All scientific phenomena that can actually be observed at school or in the immediate surroundings of the school are given priority since teachers can accompany students in the process of inquiry. Scientific inquiry is offered as an addition to a repertoire of approaches to understand and explain one's surroundings with care not to discredit existing tools or ways of knowing. In this way, students can then begin to find value in scientific inquiry which is important for longer term engagement in science and mathematics.

The design principle of being locally-rooted also refers to collective knowledge held by the elders in the community who possess culturally-relevant knowledge and practices from their ancestors. (Taking cultural traditions into consideration contributes to the societal sustainability of learning activities.) Concepts of science and mathematics found within traditional activities or artefacts are given great value at the same time respect and recognition are given to elders and ancestors. Unlike Western science teaching standards in industrialized nations that are more top-down, requiring instruction to cover topics and standards established by states, these curriculum elements are being derived from the ground up, using local examples, materials, and practices to teach key scientific concepts and ideas found in the disciplines.

In this approach, similar to the practices followed in the African Primary School Program, teachers learn by doing while taking ownership and pride over the activities and curricula. Individual teachers direct the design, fitting, and adaptation of activities for local circumstance (Carlisle, 1973; Duckworth, 1978). Research conducted in multi-lingual classrooms point to the importance of bringing culturally-relevant knowledge and practices to learning school mathematics and science. Teachers who are given some guidance and professional development in including the home language of their students can enhance the comprehension and understanding of their students (Lee, 2004). These culturally-responsive teaching approaches include using cultural artefacts, examples, familiar analogies, and other culturally appropriate communication and interactional patterns (Au & Kawakami, 1994; Gay, 2002). When these cultural and linguistic experiences are included in science instruction, students who had limited experiences in science were then capable of conducting scientific inquiry (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Having curricula that is locally-rooted is consistent with learning that is inclusive of indigenous values to bring pertinence to school learning and to leverage their cultural and linguistic ways of constructing knowledge in their home and community to the classroom.

Design Principle #2: Content must be presented in an experiential and observable manner

Learning from direct experiences is important to allow students to witness, observe and describe concepts based on their own interactions and first-hand knowledge of a shared experience with others in the community. This is especially important when designing activities for groups that possess inaccurate conceptions of science including ancestral or indigenous beliefs such as explanations for what causes illnesses, rainbows and changes in weather. Thus, teaching, discussion and concepts to be learned are grounded and based on observable phenomena or linked to real examples common to students. This will help bridge the worldview of students to that of Western science (see Bang & Medin, 2010). Because not all scientific phenomena is observable first-hand (still less without the aid of unavailable instruments) students are taught to use inquiry to ask investigable questions and apply a scientific approach towards investigating their questions and phenomena. Questions are given recognition in discussion, recorded and addressed to the extent possible, even if no satisfying answer can be achieved. No information is conveyed verbally by the teacher if the discovery can be made personally by students. Complete honesty is the rule in discussing what can and can't be observed or proved, and what information needs to be taken on faith from the textbook. Students use authentic scientific methods in investigating phenomena whenever possible. This instructional move to shift away from solely lectures and trusting an authority with blind faith is an important one to help students gain critical thinking skills.

Design Principle #3: Curricula, teaching techniques, training plans, and teaching materials must all be made locally accessible and sustainable for the long-term future

To avoid the waste of developing a curriculum that is out of reach, inappropriate, or irrelevant to the local community, the third design principle espouses the idea that all instructional frameworks and materials are created and authored in partnership with teachers using firmly achievable strategies and locally accessible materials if at all possible. This allows the curriculum to be more sustainable economically and less reliant on external sources for specialty equipment, tools, and materials. If necessary, imported materials are to be strictly supplemental. If local teachers create and adapt their own lessons, there is a stronger likelihood that they will be valued, used, and adopted by other local teachers. A goal is to have locally created texts, guides and references, while still addressing key concepts and topics that form a recognized coherence in engineering and science curricula internationally. Sustainability as a design principle addresses concurrently the environmental sustainability of the materials used, as well as the economic sustainability of materials acquisition, available non-monetary resources, and the willingness of the community to contribute resources to education. This principle is consistent with ideas found in education for sustainability and sustainable development. Declarations of the importance of sustainability as a curricular topic and approach to reforming teacher preparation programs continue to be voiced internationally, while more research is still needed to study its effective implementation in practice (Venkataraman, 2012; Rowe, 2007; Wheeler & Byrne, 2003; UNESCO, 2009).

Teaching strategies and professional development of teachers

Most teachers in Timor today limit their practice to one-way lecturing, and demonstration of learning is shown on written tests of memorization and recall, which stand as the gatekeepers to pursuing higher education. The opportunities within schools for group discussions and practicum experiences based on real, inquiry-based knowledge construction are few and far between.

In contrast, SESIM utilizes participatory, active-learning, student-centred pedagogic principles which are more common in Western schooling, but often brand new in Timor. Our hope is that SESIM continues to build a vibrant professional learning community which research has shown in other education programs to be effective for fostering reflection on instructional practice, support collaboration, and advance both group and individual learning (Hord, 2004; Vescio, Ross, & Adams, 2008; Stoll et al., 2006). For example, students (and teachers in teacher trainings) work together in groups, share common tools, discuss findings and communicate with their teacher, instead of receiving a lecture. It is through this communication that disciplines are integrated whenever it is natural, e.g. the various branches of sciences, also mathematics and social studies including economics. Teachers are trained in the exact manner that students are to be taught (this while maintaining flexibility of teacher-student ratios). In line with the approach taken by the Exploratorium's Teacher Institute[§], each teacher is given many opportunities to learn using the methods described here so as to have personal experience in addition to the theoretical knowledge (Bezin & Tamez, 2002).

[§] Exploratorium Teacher Institute - the professional development home for middle-and high-school science teachers since 1984, where the first author apprenticed and has taught others since 1992. http://www.exploratorium.edu/teacher_institute/

Teachers get considerable support in understanding the basics of these principles with many examples to reflect upon.

Though there is yet no empirical data available on the effectiveness of these initial efforts, all indications are positive: teachers are excited about using these methods, and they are popular among students. The following quotes are from evaluation forms received after two different national trainings SESIM has carried out. The participants were middle and high school teachers from all the districts of Timor. Some were new and others had been teaching for decades. A three-year degree was the most any of the teachers held and most reported having no laboratory classes at all in their college training. Some had attended various short term trainings over the last few years.

- The big advantage of this seminar was that we learned how to teach students based on the reality of their daily lives.
- Now [my] students can be made aware to witness the reality in their own everyday lives in order to actively, personally observe things and come to a better understanding.
- This seminar was better than all the other ones I've attended, since we did not just discuss theory but actually experienced the concepts.'
- I like the method wherein the teacher does not fear the students' questions because those questions will lead to new knowledge.
- I don't like that the time of this training [three full weeks] was so limited. I have high hopes to continue this type of training in the future.
- This sort of training needs to be made available to all teachers on a yearly basis.
- Material from the Encyclopaedia needs to be included in the national curriculum and trainings like this need to be carried out in all districts.
- SESIM needs branches in all districts to continue developing similar curriculum materials and carrying out trainings.

This handful of evaluative comments reflect the positive reception by teachers to inquiry and experiential learning as well as their enthusiasm for greater contact hours towards professional development. SESIM and the authors welcome further research and foresee favourable data in the future.

As mentioned earlier, SESIM, together with the first author created and published a set of experimentally and locally-rooted science activities in an Encyclopaedia, a useful form that can be shared with teachers. Like texts, the Encyclopaedia is one way to transfer teaching expertise to others; however, to fully transform an encyclopaedia into national curricula will require a plan for a viable professional development program that improves the quality of science teaching.

To build the capacity of institutions to expand this work, the practice of participatory design again applies. Both the national teacher-training institute and the national university education faculty in Timor should ideally be included and involved in the growth of this new pedagogy and the work of SESIM. These institutions are positioned to affect hundreds of teachers each year, and can advance design principles that are locally-relevant, effective and meaningful teaching methods and approaches to the national syllabi. At this time, both of these institutions are struggling to clarify their own positions, missions, identities and priorities within the Ministry of Education. SESIM is slowly working to build solid relationships with both of these institutions, as well as other relevant institutions. SESIM expects to increase the support and acceptance it gets from the Ministry as it continues to serve teachers with effective practices.

Discussion, conclusions, and implications for science education

From the three examples and design principles, we have provided an introduction to a participatory, experiential approach to developing science and mathematics curriculum elements and carrying out teacher training emerging from a group of dedicated teachers in Timor-Leste. Local teachers with the help of a Western-trained science teacher developed and instructed with activities that made use of local expertise, folk knowledge, and readily accessible local resources.

This work relied heavily on an inquiry-based, learning-by-doing-together approach both to develop curricula elements as well as teach students and prepare teachers. This pedagogical approach is also consistent with social constructivist approaches to learning and collaborative knowledge building, and is necessarily grounded in everyday practices, truth-seeking, and forming systems of rationality, giving students the basic tools to conduct their own investigations and pose investigable questions in experimentation and dialogue with others (Blumenfeld, Marx, Patrick, & Krajcik, 1996). All students regardless of prior formal schooling possess knowledge of the natural world as well as a set of guiding beliefs (diSessa, 1988; Hammer, 1996). Teachers and students come to a classroom with a range of beliefs, epistemologies about the nature of science, and values of scientific inquiry as a learning process (Lederman, 1992; Anderson, 2002). The students and teachers in Timor-Leste are no different. As they gain more opportunities to see how ideas are developed and revised through a process of conjecture, testing, argumentation and reflection, they'll also gain consciousness of how their own beliefs stand in relation to science and be able to discuss this freely.

As science educators, our goal is to build upon these ideas and intuitions, and offer students and teachers usable methods and criteria for establishing validity. Students engage in first-hand experiences so they can see, do, wonder, experiment, collect and record data, and explore phenomena directly. This approach to creating more contextualized education and the idea that science learning should be more closely tied to students' existing knowledge and experiences is not a new concept, but is often forgotten in modern science education, especially in the remote, resource-limited communities that could make the best use of it. Our design principles offer some starting points and guidelines for supporting the design of locally-rooted curricula and inquiry-based instructional practices. The practice of learning, sharing, and teaching others through inquiry is the common thread that allowed people from Timor-Leste to investigate, invent, and document their teaching ideas into more formal curriculum elements.

A democratic ideal is that science and mathematics education should be provided for all learners, and a tendency of education institutions who attempt to forward this ideal is to impose a well-tested existing science curriculum (perhaps from one state, country, or nation) into their new setting. However, communities with few Western scientific tools and resources, and deeply rooted non-Western traditions face additional barriers having to cross cultural boundaries, potentially assimilating new systems of beliefs, language, and practices about how to make sense of the natural world (Kawagley, Norris-Tull, & Norris-Tull, 1998). An area of future research could engage more systematic study in examining the beliefs of students and their values in scientific ways of knowing as new educational innovations are introduced. The worldview of the students and teachers in Timor-Leste is a rich area of exploration especially to see how their views may (or may not) develop in relation to their beginning to think more and more with the views of Western science, and how their communities develop their shared understanding of science practices.

Culturally-relevant curriculum is just one aspect of providing a contextually relevant education, which is much needed in a rapidly evolving nation. To make progress in education and establish an effective education system, a curriculum that is accepted, co-designed by participants with mutual respect and trust, and adopted by its users is of critical importance. Organizing and establishing professional development to ensure teacher quality is also a necessary part of this evolving education system to establish an important foundation through means of an accepted certification process (Earnest, 2003). Professional development is effective when the training provided is intensive and sustained over time, focusing on both academic content, active learning, collective participation, and coherence with school and everyday practices (Garet, Porter, Desmione, Birman, & Yoon, 2001). From our experiences, the design-based approach we have been using with great success addresses concurrently the development of teachers and the development of a meaningful curriculum that can they can implement.

In Timor-Leste, rich with culture though still recovering from a traumatic colonial legacy, effective school improvement and change in education will be a long-term process that takes place only when on-going teacher development is carried out over the course of the entire academic year, along with leadership training for school administrators. Moreover, research and evaluation is ideally done concurrently to carefully document the development while curriculum is scaled to all teachers and teacher professional development is formalized. Future studies that make use of design-based research approaches as well as examine issues related to local context and practices can be helpful to refine locally valuable innovations while also developing more globally usable knowledge for the field (DBRC, 2003; Sandoval & Bell, 2004).

In summary, Timor-Leste as a place offers a unique contextually-rich environment to conduct cross-cultural studies to further explore the localized context for science and mathematics curricula, teacher development, contrasting and converging views of Western science and worldview of students. Our work so far has simply generated working design principles for education development at the local and regional levels. We are optimistic that this approach and these design principles can have a national impact when a participatory development approach is taken as a first step to engaging all stakeholders.

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