

Watering the Tree of Science: Science Education, Local
Knowledge, and Agency in Zambia's PSA Program

By

Emily Lample

Dissertation

Submitted to the Faculty of the
Graduate School of Vanderbilt University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in

Community Research and Action

December, 2015

Nashville, Tennessee

Approved:

Torin Monahan, Ph.D.

James Fraser, Ph.D.

Kimberly Bess, Ph.D.

Rogers Hall, Ph.D

Acknowledgements

This work would not have been possible without the financial support of the Williams College Tyng Scholarship.

Sincerest gratitude as well to each member of my dissertation committee, Dr. Kimberly Bess, Dr. Jim Fraser, Dr. Rogers Hall, and especially, my committee chair, Dr. Torin Monahan, for their ongoing guidance and advice during this project and my entire graduate school career.

Many thanks to the students, tutors, coordinators, and administrators at Inshindo Foundation for their hospitality, friendship and generosity of time during my stay in Zambia.

Thank you as well to my family and countless other friends and colleagues, whose encouragement and support has been crucial during this process.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	ii
LIST OF TABLES	v
LIST OF FIGURES	v
Chapter	
I. INTRODUCTION.....	1
Science education for development: Giving shape to a framework	4
Science, local knowledge and agency in science education for development	40
Introduction to the case: The Preparation for Social Action Program in Zambia	43
The background: Education and development in Zambia	44
Approach to research.....	68
II. RETHINKING SCIENCE AGENCY	80
Critical science agency for community development	81
Researching science agency	95
Learning science in PSA	97
Ways of using science	103
Instances of critical science agency for community development	105
Discussion	132
Conclusion.....	144
III. CONCEPTIONS OF KNOWLEDGE AND SCIENCE AGENCY	145
Meaning and agency in communities of practice	146
Epistemology in science education for community development.....	156
Approach to research.....	162
Sources of knowledge: ‘The goodness is that we share ideas’	165
Knowledge certainty: ‘PSA doesn’t come with answers’	178
Conceptions of knowledge and science agency	190
Knowledge in the conceptual framework of the PSA program.....	215
Discussion	219
Conclusion.....	228
IV. SCIENCE, LOCAL KNOWLEDGE, AND COMMUNITY DEVELOPMENT ...	229
Problems of science and knowledge in development.....	230
Framing local knowledge	232
Community development and knowledge	252

Discussion	265
Conclusion.....	269
V. CONCLUSION.....	270
Flyvbjerg's questions	273
REFERENCES	278

LIST OF TABLES

Table	Page
1 Science Content in PSA Texts	60
2 Local Knowledge in PSA Texts.....	64
3 Ways Students and Tutors are Using their Science Learning.....	104
4 Kanini 3 Posters at the Community Meeting.....	127
5 Individual and Collective Benefits of Science Learning for the Six Cases	138
6 How Simon’s Science Agency Grew Through PSA.....	193

LIST OF FIGURES

Figure	Page
1 Simple Model of Science Learning for Community Development	134
2 Simple Model of Hillary’s Use of Science Learning for Community Development.....	135
3 Simple Model of Timothy’s Use of Science Learning for Community Development.....	136
4 Simple Model of Alex and Insofu 1’s Use of Science Learning for Community Development.....	137
5 Two Dimensions of Benefits of Science Learning for Six Cases.....	140
6 Model of Elliot and Insofu 2’s Use of Science Learning for Community Development.....	226
7 Model of Jason and Kolwe 1’s Use of Science Learning for Community Development.....	227

CHAPTER I

INTRODUCTION

Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world. Science is the highest personification of the nation because that nation will remain the first which carries the furthest the works of thought and intelligence.

- Louis Pasteur, quoted in Dubos (1960, p. 85)

Science and technology (S&T) capabilities are fundamental for social and economic progress in developing countries; for example, in the health sector, scientific research led to the development and introduction of oral rehydration therapy, which became the cornerstone of international efforts to control diarrheal diseases. Research also established that two cents worth of vitamin A given to children every six months could reduce child mortality in many countries by over one-third. In agriculture, rice-wheat rotation techniques have significantly enhanced food production in South Asia. In Central America, scientifically based natural resource management has been essential in developing the tourist industry, a major source of foreign currency...

Unfortunately, many developing countries, particularly the poor countries of Africa, do not have the human resources, physical and economic infrastructures, and access to capital to take full advantage of the S&T expertise and achievements of the United States and other industrialized countries. Nevertheless, countries at all levels of development have a strong desire for more robust S&T capabilities. And some capability to understand the potential and limitations of S&T, to select and effectively utilize suitable foreign technologies, and to develop innovations is need in every country.

- U.S. Agency for International Development (USAID), 2006, p. 1-2

I was born into a culture that continues to exercise greater influence and power over behavior than modern science does, or will ever do... Every culture enjoins on its members respect for certain entities. Modern science does not find a place in *our* pantheon.

Far from it. From this side of Suez, in fact modern science appears akin to an imported brand of toothpaste. It contains elaborate promises and much sweetness and glamour. It can be used, is often used (many times pointlessly), yet can be dispensed with at any time precisely because it is still largely irrelevant to *life*...

In *our* society... the moment we find toothpaste unavailable, we return to neem sticks, or cashew or mango leaves, or mixtures composed of ginger, charcoal and salt. All excellent, locally available and dependable materials for keeping the mouth fresh and disinfected and the teeth clean.

...Like the early morning toothbrush, science is considered a precondition for a freshly minted worldview uncontaminated by unlearned or emancipated perceptions. For its part, it offers to flush out the many disabling superstitions from all those hidden crevices of a society's soul, to eliminate any and every offending bacteria, to produce a clean and ordered world. Most important, it promises a materialist paradise for the world's unprivileged through its awesome, magical powers...

Such an irreverent view of modern science will not be comfortable for those who have chosen to remain imprisoned within the dominant present-day perceptions of the age. But for us, it always was *another* culture's product, a recognizably foreign entity. We eventually came to see it as an epoch-specific, ethnic (Western) and culture-specific (culturally entombed) project,

one that is politically directed, artificially induced stream of consciousness invading and distorting, and often attempting to take over, the larger, more stable canvas of human perceptions and experience.

- Alvares, 1992, p. 223-4

In the post-modern era, science, and its role in human progress, is a contested domain. For some, it is the greatest achievement of Western society, something the U.S. and “other industrialized countries” can contribute to “developing countries,” provided those nations have the “human resources, physical and economic infrastructures, and access to capital to take full advantage” of U.S. “expertise and achievements.” To others, it is a “foreign entity,” with “elaborate promises” and a propensity for “invading and distorting,” an unnecessary alternative to “excellent, locally available and dependable” options that are equally valuable.

These brief excerpts provide just snippets of a reoccurring debate found in development studies (e.g. Rahnema & Bawtree, 1997; Sachs, 1992; Sillitoe, 2007), science studies (e.g. Harding, 1998; Leach, Scoones, & Wynne, 2005), and science education (e.g. Semali & Kincheloe, 2002; Snively & Corsiglia, 1998). The debate faces traps of dichotomous thinking, taking up more elaborate versions of the following sorts of questions: Is science the arbiter of absolute truth and as such universally beneficial—implying a particular prescription for the progress of all human societies—or is it hegemonic, at odds with human diversity, and a danger to many ways of life? Is traditional knowledge a distinct and discrete knowledge system, on par with ‘Western’ science and a valid alternative to it, or are local knowledge, beliefs, and practices mostly ornamental, to be overlooked, or when possible leveraged toward the aims of modernity? Underlying such disputes is the conflict between modernism and post-modernism, and the question of what comes after them.

This study searches for a more reasonable middle ground within a particular sphere of activity: science education and its contributions to community development. In so doing, it examines the case of a single educational program in Zambia to understand (1) ways that students draw from and conceptualize both scientific knowledge and local knowledge, and (2) how such conceptualizations shape the ways that they use what they learn in their own lives and in their contributions to the community. In this way, the study seeks to move beyond the superficial and problematic ways that science and local knowledge are cast in mainstream development discourse and the potential paralysis rooted in cultural relativism and exclusively critical analyses.

This introductory chapter sets the stage for the analysis found in the paper as a whole. It defines the problem of science education for development by looking at the literature through the lens of phronetic social science research, as identified by Flyvbjerg (2001). To frame the discussions that follow, it then develops the concepts of ‘development,’ ‘science,’ and ‘education’ in the manner in which they will be used in this study. This establishes a particular notion of ‘science education for development,’ one which has been articulated occasionally in science education literature, but has received little empirical attention. Once these terms have been given shape, it is then possible to introduce the objectives of this study and the intended contributions to the literature. Following this, the specific case examined in the study, the Preparation for Social Action program in Zambia, is introduced through a survey of education and development in Zambia, a brief history of the program’s emergence in Colombia and its key characteristics, and finally, a look at its establishment in Zambia. The final two sections of the chapter de-

scribe the research methods of the study and then provide an overview of the next four chapters of the paper.

Science Education for Development: Giving Shape to a Framework

The postmodern move in academic thought has, among other things, drawn attention to the harmful consequences of systems of belief and practice once unquestioned in their positive contributions to human society. Lyotard (1984) characterized the postmodern trend as, in its most basic essence, “incredulity towards metanarratives”—the inability to believe any longer in those broad, underlying, ‘quasi-mythological’ beliefs about human purpose, human reason and human progress derived from the Enlightenment. While modernity championed the accomplishments of human rationality, and the potential for a set of objective and universal standards in the ‘scientific method’ to lead to a progressively better human condition around the world, many have called this into question. Within the philosophy of science and social studies of science, romanticized and simplistic notions of the scientific method have been widely challenged (e.g. Kuhn, 1962; Lakatos, 1970; Latour, 1987). Feminist and postcolonial perspectives within these fields question possibilities of objective, culture-free positionality in science (e.g. Haraway, 1989; Harding, 2008). In development studies, many have voiced concern that science and the framing of ‘development’ have both been instruments of homogenization and hegemony, imposing a particular worldview that casts the benefactors of development as both the model for others to follow and ultimately its primary beneficiaries (e.g. Rahnama & Bawtree, 1997; Sachs, 1992).

Such criticisms seek to defend social, cultural, and epistemological diversity from what is considered an oppressive influence of science and development. While drawing attention to potential homogenization and mounting injustice is crucial, care must be taken lest these criticisms overlook the characteristics and conditions that gave rise to the influence of science and development in the first place. Despite the many consequences that can be tied to the development enterprise and the ways in which it has served to further the interests of its purported benefactors, the widespread conditions of poverty remain a pressing challenge for the world community. While some aspects of modern science closely relate to Western cultural values, and such values manifest themselves in the technologies that science makes possible, the capacity of the scientific enterprise to describe and predict the natural world is unparalleled in any knowledge system that may be considered to compete with science.

Rather than concentrate on the merits or hazards of the scientific and development endeavors, attention here will be turned to how they might be more appropriately framed, in hopes of contributing to the advancement of discourse and practice. This reflects the position on social science research of Flyvbjerg (2001), who points out that social sciences cannot fashion themselves after the natural sciences in making models of a reality over which they have little role in shaping. Instead, the social sciences are intimately linked with shaping social reality, informing practical reason through phronesis. It is from this perspective that the present study explores the potential contributions of science education to development. Duly aware of criticisms of both science and development, it focuses empirical inquiry on an understanding that can foster better practice. In so doing, it seeks to be attentive to the many valuable criticisms found in literature on development,

science studies, and science education, while building upon theories and descriptions that seek a way forward. Towards this end, it draws from a stance articulated by Bohm (1981), which considers theories not an articulation of reality as is, but rather a source of insight into a reality too complex to be entirely captured by any given description. This stance, and the reasoning behind it, is conveyed in much greater detail in a later section of this chapter, but it is important here in orienting the review of the literature below.

The sub-sections that follow, then, examine questions of science, development, education and science education towards the aim of exploring potential contributions of science education to development. They begin with an overview of a few ways in which the study of science has been called to contribute to development, then continue with a critical examination of the development, science, and education enterprises, and finally conclude by articulating a more refined vision of how science education can advance some of the aims of development.

The Call for Science Education for Development

The accomplishments of science in recent centuries, through its systematic inquiry into the workings of the universe and the vast technological advancements it has made possible, have earned it a place of key consideration in the progress and prosperity of human societies. From this perspective, the teaching of science is integral to involving greater numbers in scientific pursuits so that the endeavor may continue into the future. The international development enterprise, in its efforts to improve conditions of life around the world, has seen science and science education as particularly crucial to achieving the ends it identifies (Bamiro, 2007; Dei, 2003; USAID, 2006; UNESCO,

1983). The logic shaping such an approach is captured in the following description: “the understanding of the physical world gained through research in the basic sciences is acknowledged as the foundation for technological innovation, which in turn is seen as a major underpinning for socio-economic progress” (Garrett & Granqvist, 1998, p. ix). Science education has been lauded as facilitating the expansion of science and technology in less materially prosperous regions, making investment in it “one of the most critical sources of economic transformation in the newly industrial countries” (UN Millennium Project, 2005, p. 88). The teaching of science, then, has frequently been linked to development through its potential to raise up workers who better contribute to the economy.

On the African continent, as in many places, the development of human capital through science education has been identified as vital to economic development (Ogunniyi, 1996; Zymelman, 1990). Towards this aim, many African countries have enhanced educational facilities, opened curriculum development centers as well as science and technology research institutes, and created regional examination boards. In ministerial conferences held in Tananarive, Addis Ababa, and Lagos in the early 1960s, governmental leaders from several countries sought ways make science teaching compatible with their newly won independence (Ogunniyi, 1986). During colonialism, science had been taught as dogma rather than systematic inquiry, and with independence it was felt by many that a different manner of teaching was required. The series of conferences in the 1960s emphasized policy development, and gradually a pan-African policy took shape that centered on “equipping each pupil with desirable scientific knowledge, skills, and attitudes” (Ogunniyi, 1986, p. 112).

Beyond training human resources for universities and research facilities, governmental leaders and education researchers have articulated the contributions of science education to a nation in terms of a broader science ethos. Dr. Ngubane, former Minister of Arts, Culture, Science, and Technology in South Africa, for example, described three specific contributions of scientific literacy to the promotion of development: (1) improved decision-making in everyday life, and consequently better participatory democracy, (2) the development of a workforce with appropriate skills for economic growth and social development, (3) the production of science and technology experts who can generate and apply knowledge to solve local problems (Ngubane, 2003). Along the same lines, Savage and Naidoo (2003) characterized science education as leading to development by both affording access to scientific knowledge, for science-related careers, and through the development of creativity and science-related problem-solving, which aids in the activities of people at all levels of society. They described the latter as fostering a desperately needed “problem-solving, ‘tinkering’ ethos that contributed so much during the period when Europe and the USA industrialized” (Savage & Naidoo, 2003, p. 19). The language of education policy in various countries has emphasized creatively employing science for personal economic benefit. In Uganda, science education was described in governmental policies as creating “job-makers” rather than “job-seekers” and in Tanzania it was an important part of “education for self-reliance” (Yoloye & Bajah, 1981).

These are just a few of many articulations of the ways in which the teaching and learning of science have been regarded as important to progress in governmental policy, particularly in the decades just after independence. On the basis of such perspectives, science education, particularly at the tertiary level, has been given special consideration

in the development enterprise. Yet, the high hopes for science education's contribution to development identified in the pan-African conferences of the 1960s met with disappointment in the decades that followed. Analyses undertaken in the 1970s about the state of science education in Nigeria (e.g. Kalamananthan, 1970; Teibo, 1975) and Kenya (Indge, 1976) reported unsatisfactory conditions of science teaching, and conferences of the Forum of African Science Educators in 1980 and 1982 reiterated concerns about the poor state of science teaching (Ogunniyi, 1986).

A few different explanations for the shortcomings of science education have been put forth. One of the challenges faced in many parts of the continent in the first few decades post-independence was the sharp increase in student population, as education became more widely accessible (Ogunniyi, 1986). Various governments sought to tackle this issue through efforts such as crash programs for teacher training, the production of low-cost science equipment, and policies that favored admission of university students in to science and technology-related fields. Other socio-economic factors, such as political instability, population growth, inflation and collapsed economies, environmental degradation, high unemployment, migration of the highly educated, and excessive debt burdens have also no doubt contributed (Gray, 1999; Ogunniyi, 1996). Researchers in various countries have made similar claims related to monetary shortcomings. Ndirangu, Kathuri, and Mungai (2003), for example, attributed poor performance in Kenya to higher school enrollment without a corresponding increase in the monetary and training resources available to teachers. In contrast, in Botswana, according to Ogunniyi (1995), the relatively strong economy has generated sufficient resources for the public funding of

education, but government gave insufficient attention to upper secondary school and the training of science teachers.

In addition to those factors, many education researchers have pointed the finger at culture as an impediment to effective science learning and use. Jegede (1997), for example, lamented culturally inappropriate science content, noting that, post-independence, most African nations borrowed or adapted science curricula from countries in Europe and North America in hopes of attaining high academic achievement for their citizens. Success with these materials, he considered, has been limited. Part of the problem, Jegede argues, is that there was no philosophical foundation for one or another approach. Along similar lines, Savage and Naidoo (2003) traced the problems of science education on the continent back to the manner in which science was spread there. They described that when science and technology were ‘introduced’ to Africa, there was an underlying assumption that no science and technology existed on the continent—knowledge and practice had to be imported and transplanted. African scientists were largely trained abroad and developed expertise outside of the institutional conditions of science in Africa and far removed from the needs of African nations. Imported curricula were similarly decontextualized and alien to African societies. Most science and technology education in Africa, Savage and Naidoo contend, continues to be irrelevant and dysfunctional to development needs on the continent. Such accounts offer broad strokes analyses that emphasize the similarities in the experiences of African nations, particularly as a result of colonialism, with less attention to diversity of experience. A few research projects, though, have examined the implications of cultural dissonance in particular cultural and educational contexts. Akatugba and Wallace (1999), for example, looked at how cultural heritage affect-

ed proportional reasoning in Grade 12 students' study of physics in Nigeria, as students were culturally dissuaded from asking questions and assigned to teachers and science in general absolute authority and truth. In response, however, some such as Dzama and Osborne (1999) have countered that culture has been given too much credit for negatively affecting science education. Looking at the experience of students in Malawi, they argued that poor performance in science education results from a lack of vocational incentives.

Despite the limitations in the way that science education has proceeded in many African countries post-independence, most of these authors have reiterated their belief in its importance for development in the region. Those concerned with cultural dissonance have advocate for more culturally sensitive reform. For example, Jegede (1997) recommended a new approach to science education rooted in African experiences, one that generates information about natural phenomena in Africa, connects fundamental science principles to indigenous practices, enables people to develop indigenous technologies while appreciating the underlying science of them, and upholds and reinforces local values. Savage and Naido (2003) proposed the promotion of a “culturally sympathetic problem-solving science and technology culture” (p. 8), one that takes problems from the learners' environment, is culturally appropriate, and makes use of local resources rather than foreign imports. They considered that an approach to science education based on teaching science inquiry helps to develop initiative, teamwork, and determination, also assisting in the development of qualities that promote good citizenship, including comfort with uncertainty, the ability to make evidence-based decisions, and the ability to distinguish truth from fraud. Again recommendations tend to make sweeping statements that

they apply across the continent. Those concerned with social and economic impediments often advocate policy reform and steps towards global economic justice (e.g. Gray, 1999; Ndirangu, Kathuri, & Mungai, 2003; Ogunniyi, 1995).

The discussion of the role of science education in development on the African continent provides a window into thinking about the role of science education in development more broadly. Much of the focus on the development enterprise has been on that continent and Africa is often cast as the quintessential image of a region in need of development. According to Ferguson (2006), conceptually “Africa” has most frequently been identified with crisis and defined in terms of what it lacks—a “radical other” for Western constructs of civilization and enlightenment. Such standing makes the region an interesting one in which to consider the complexities of the issue of science education for development. Any thoughtful exploration of science education for development, however, would have to take into account the ways in which the development enterprise has been extremely problematic, the question of what science is, including where its merit lies and concerns of its use in subjugating others, and the multiple and often contradictory perspectives on education and the nature of learning. In other words, any meaningful look at science education for development must begin by addressing the question of what one actually means by the terms ‘science,’ ‘education,’ and ‘development.’

Rethinking Development

Perhaps the most problematic of the three terms is the term ‘development’ as used in reference to the international development enterprise. Development, in that context, had a questionable inauguration, has met with little success since then and has raised a

number of very serious and legitimate concerns. For these reasons, many have called for the end of development and have shifted attention to ways of fighting back against development (see Escobar, 1994; Rahnema & Bawtree, 1997; Sachs, 1992; Shiva, 1997). To them, development has caused such damage through the paternalism and covert manipulation found one part of the world's efforts to meddle in the affairs of other regions that the entire endeavor should be abandoned. The major criticisms of development raised by these authors are insightful and important for consideration of any purposeful effort to address social and economic conditions in a region; they are explored in the paragraphs that follow. Development critics have questioned the motives, the assumptions, and the goals of both the development enterprise and the spread of modern science in general. In so doing, they have drawn attention to complex issues of power, culture, values and the discourse shaping such endeavors. Yet, for reasons to be explored at the end of this section, there is also value in not completely forsaking all discussions of development. The current state of human development—including the living conditions of the majority of the world's population, the distribution of wealth, access to opportunities to contribute to society in ways one considers meaningful, rates of prevalence of avoidable diseases, and access to enriching education worldwide—is neither acceptable nor inevitable. The paragraphs below explore a number of limitations of the construct of development through the major criticisms of post-development thinkers with the aim of refining the construct for the purposes of this paper.

Development's false binary. While notions of social progress and civilization-building date back to antiquity, the birth of the modern notion of development can arguably be traced to the middle of the twentieth century. Many attribute the conceptualization

of development to President Truman's Four Points address in 1949, at the end of World War II (e.g. Escobar, 1994; Esteva, 1992; Rist, 2002). The following brief extracts of the speech convey the aims of the development effort as initially defined:

...we must embark on a bold new program for making the benefits of our scientific advances and industrial progress available for the improvement and growth of underdeveloped areas.

More than half the people of the world are living in conditions approaching misery. Their food is inadequate. They are victims of disease. Their economic life is primitive and stagnant. Their poverty is a handicap and a threat both to them and to more prosperous areas...

I believe that we should make available to peace-loving peoples the benefits of our store of technical knowledge in order to help them realize their aspirations for a better life...

Our main aim should be to help the free peoples of the world, through their own efforts, to produce more food, more clothing, more materials for housing, and more mechanical power to lighten their burdens. (quoted in Rist, 2002, p. 71)

One major concern of critics of development is that with this language Truman introduced a new vocabulary that recast relations between nations into categories of 'developed' and 'underdeveloped'. It defined the lives of a large proportion of humanity in terms of what was lacking. As Esteva (1992) described of the speech:

Underdevelopment began, then, on 20 January 1949. On that day, 2 billion people became underdeveloped. In a real sense, from that time on, they ceased being what they were, in all their diversity, and were transmogrified into an inverted mirror of others' reality: a mirror that belittles them and sends them off to the end of the queue, a mirror that defines their identity, which is really that of a heterogeneous and diverse majority, simply in the terms of a homogenizing and narrow minority. (Esteva, 1992, p. 2)

According to this binary conceptualization of development, development is the activity of remaking certain parts of the world in the image of others. It implies a need to move 'underdeveloped' nations into the category of 'developed' according to a particular vision of progress, one rooted in Western culture and assumptions (Sbert, 1992). The criticism articulated by Esteva, Sbert, and others in this regard can serve as a broader warning

against any tendency to cram the enchanting diversity of human social practices, structures, and beliefs into two over-simplified categories of any kind—be they developed and underdeveloped/developing, global North and South, Western and non-Western. Such a tendency is so pervasive that many scholars, even some post-development scholars themselves, have fallen victim to its trappings.

Contradicting objectives. The development initiative, as articulated by Truman in 1949, seeks to help various peoples of the world realize their aspirations for a better life. Yet, as many have noted (e.g. Escobar, 1994; Illich, 1997), the agents of development tend to be major development organizations from North America, Europe, Japan, and elsewhere. These operate from a view of “a better life” rooted in the experiences and values of their own cultures, which usually contrast with the values and preferences of development’s intended beneficiaries. For example, in many of the most common development approaches, economic growth has taken center stage as a solution to the conditions problematized by development. It has become unambiguously associated with good (Latouche, 1997). Industrialization and technology are less considered means that can make positive or negative contributions to society, and are increasingly considered goals in themselves. As a result, development aims to achieve greater “well-being” boil down to “well-having” and complex considerations of “quality of life” are limited to focus on the “quantity of gadgets” produced and consumed (Latouche, 1997, p. 139). In other worlds, the purported aims of helping others realize their own aspirations of a better life have in many ways simply translated into the global proliferation of materialism and consumerism.

Adding to the complexity of development's contradictory objectives are the ways in which the development enterprise benefits those nations offering the aid. Truman's Four Points speech hinted that one of the purposes of development was to protect U.S. interests by promoting stability in other regions, as "their poverty is a handicap and a threat both to them and to more prosperous areas" (quoted in Rist, 2002, p. 71). Sachs (1992) emphasized that development has from the beginning been based on a "one world" model that promises world peace through pursuance of global prosperity in one common market. While the model considers that as all nations participate in the global market, each according to its comparative advantage, all will prosper, Sachs points out that the model rests on faulty logic. If each country specializes production according to its natural resources and historically produced conditions, all will not prosper equally; those that produce more complex products, pharmaceuticals as opposed to raw sugar, for example, will ultimately experience stronger growth as they internalize the benefits of more sophisticated production. Furthermore, interest payments on loans made to nations in Latin America, Africa, Asia, and the Pacific by the IMF, the World Bank, and other creditors have brought hundreds of billions of dollars into creditor nations at the expense of those nations intended to benefit from development—\$702 billion between the years 1982 and 1990 on interest payments alone (George, 1997). Between those same years, according to George, the principal and interest of the debts totaled \$1,345 billion. This is part of a larger trend whereby the gap in wealth between richest and poorest countries has drastically increased since the inception of the development enterprise (Sachs, 1997). Development has not only failed to achieve its objectives of contributing to global justice and prosperity, it has arguably furthered injustice and poverty.

Science and development. A third criticism of how the development enterprise is commonly conceptualized was perhaps best articulated by Escobar (1994). His examination of development as a historically produced discourse highlighted the central role of science and technology in development from its inception and questioned the manner in which they were employed. Science, technology, and capital were considered main ingredients in development—ones that needed to be supplied by countries already considered ‘developed.’ Technology, seen as “neutral and inevitably beneficial,” was believed to both amplify material progress and give it direction and meaning (Escobar, 1994, p. 36). Yet, critics like Escobar, Alvares (1992), and Shiva (1997) argued that the spread of science in development brought with it foreign cultural values that in many cases undermined local values and practices. Often, they suggested, science was transferred to countries through the education of an elite class of ‘modernizers’ who were alienated from their own culture (Alvares, 1992). Consequently, institutions capable of generating the necessary knowledge were established and “the ‘tree of research’ of the North was transplanted to the South,” (Escobar, 1994, p. 37). This criticism is explored in greater depth at various points in the chapters that follow.

Beyond development’s end. The limitations to development identified above certainly call into question the utility of any approach built upon the objectives framed by the development enterprise. And from that point of view, calling for the end of development seems reasonable. Yet, as Ferguson (1999) noted, little has been achieved by celebrating the end of development. The “post-World War II conceptual apparatus of development” did not create poverty and social inequality around the world, he asserted, and as such, its demise cannot cause them to disappear (Ferguson, 1999, p. 248). Instead, he

argued that intellectual efforts should focus on what comes after development—“both as an intellectual and cosmological framework for interpretation and explanation, and as a progressive political program for responding to its disastrous economic and social failures” (Ferguson, 1999, p. 250). In thinking about what comes after development, given its many failures and limitations, one possibility is to throw out development as a construct entirely, and frame efforts to achieve better living conditions and equity worldwide in other terms. The danger in doing so, however, is to lose the insights generated by decades of theory and action, found in both the criticisms of development and those more able development thinkers whose positions overcome some of the shortcomings identified by critics.

This paper is undertaken from the perspective that any area of social endeavor must be gradually improved and refined through the efforts of a community of researchers, theorists, and practitioners—hopefully most people engaged in all three activities—in conversation with one another. While the aims of development articulated by Truman have been proven to contribute to greater economic disparity and the proliferation of elements of Western culture that are not very desirable, the need for purposeful effort to improve material conditions, social structures, and individual possibilities remains. The paper proposes that such aims continue to be addressed under a revised construct of ‘development.’

In light of the aforementioned criticisms, the conception of development addressed here has the following characteristics, which are drawn from a variety of approaches to international and community development: (1) ‘Development’ is not an endeavor directed at particular parts of the world. Nowhere on the planet are living condi-

tions such that all members of society are free from poverty and from modes of oppression and exclusion, living lives in which they can all contribute to society in a manner they consider meaningful, having access to enriching education and means to address their health problems. As such, all societies can be considered to be in need of a process of developing and improving the conditions of their society (Campfens, 1997). Development as conceived here is a requirement of all parts of the world, though each particular nation or community may find itself needing to focus on something somewhat different than others. (2) Development as taken up here is not something that a few people can do on behalf of others. If the activity of development, as well as consideration of what needs to be addressed and how, are left to a few, it is almost inevitable that some will benefit more than others, that the shape society takes will reflect the perceptions of some to the detriment of others. All must play a part reflective of their inclinations and capacities. Further, it is in the act of playing a part and contributing to society that some of the aims of development come to bear (Sen, 1999). (3) Following from the previous point, if development is an activity involving all, the specific aims of such processes cannot be fully and definitively identified and articulated in advance, for this would ascribe responsibility to a few, those currently having a voice. Instead, objectives are forged and refined in an ongoing manner as more and more come to participate in what is necessarily a consultative process. Nevertheless, there may be particular ways of framing development aims that currently appear to be more beneficial than others, and allow for reflection about such aims to move forward. For example, Sen (1999) casts development in terms of freedoms of the individual—such as freedom to live to old age, freedom to live in a safe environment, and freedom to engage in economic transactions. In that way, he iden-

tifies economic growth, and indicators of growth, not as ends of development, but rather means of working towards those freedoms. Along similar lines, Nussbaum (2000) argues for conceptualizing development in terms of capabilities. She identifies ten core capabilities, but then asserts that these can and should be modified as more people take them up. (4) Another criticism of international development not explicitly identified above is that development has been conceptualized largely in terms of individual needs and benefits. Though changes to governmental systems and policies have also been integral to development, beyond these, development has been focused on the individual. The conception of development being put forth here draws from perspectives such as that of Evans and Prilleltensky (2007) and Maton (2008) to consider community development as involving individuals, institutions, and communities in processes of social change, each of which are also changed by that involvement.

Such a conception of development, while articulated only briefly here, forms the basis of the consideration of science education for development in this paper. The premise is that the teaching and learning of science has something of value to contribute to processes of the sort of development described here. The case study taken up in this paper will provide a means of considering this notion of development in greater depth, but ultimately it would require a community of people thinking, acting, and writing in relation to this construct to solidify it and address its intricacies. The exploration of science education for development here requires a similar examination and articulation of the notion of science, the topic of the next sub-section.

Community development. Before addressing the topic of science, however, it is worth taking a brief moment to address another concept related to the notion of develop-

ment used here, that of community. Development as examined in this paper is taken largely at the level of community development. This is not to ignore the important role of government policy and the flow of financial resources from one nation to another but, as the exploration will make more clear, thinking about development at the level of community allows for the dimensions of development identified in the previous paragraphs to come to the fore. The word community can be used in a wide range of ways. It is employed in this paper in two specific ways. First, ‘community’ is used in reference to a group of colleagues, usually scientists, social scientists, or practitioners of some sort, in dialogue with one another as a part of a shared exploration of some topic. This is the way the term was used in the penultimate sentence of the previous paragraph. Second (and more commonly), when speaking of community development, it refers a group of people associated with one another through geographic proximity, and as a result (a) having the possibility of interacting with one another with some frequency, (b) facing similar and interconnected environmental, social, and economic conditions, (c) interacting with the same collection of institutions, (d) often sharing language, customs, beliefs, and/or other meaning systems, and (e) as a result of these, having the potential for collective action. The program taken up here as a case study uses community to refer to geographic communities of a specific size, “either your entire village or town if you live in a rural area, or your neighborhood in the city if you belong to an urban population” (FUNDAEC, 2010, 1). Since such a conceptualization fits with the notion of community articulated here, and for the sake of clarity and congruence, this same sense of community will be utilized in the entirety of this paper when ‘community’ is discussed in the context of community development.

Community development involves taking the community (village or neighborhood) as the unit of development, rather than the individual or nation (Daly & Cobb, 1994). It recognizes an inseparable tie between the well-being of the community and the welfare of the individuals that make up the community. As such, it breaks from the individualistic visions of development and well-being rooted in predominant economic theory. This theme of the inter-connectedness of individual and collective well-being runs throughout this paper and is integral to the conceptions of development pursued here.

What is Science?

The second term requiring thoughtful consideration for the aims of this paper is science. Science has received criticisms along many of the same lines as development. In fact, as mentioned above, some critics of development have also been critics of science as another vehicle of Western hegemony. Shiva (1997), for example, describes the “dominant stream of modern science” as “a specific project of Western man which came into being during the fifteenth, sixteenth, and seventeenth centuries” (p.162) rather than the universal, value-free system of knowledge it is commonly considered. She describes it as hegemonic in the following way:

It has hidden its ideology behind projected objectivism, neutrality and progress. The ideology that hides ideology has transformed pluralistic traditions of knowledge into a monolith of gender-based, class-based thought, and transformed this particular tradition into a superior and universal tradition to be superimposed on all classes, genders, and cultures which it helps in controlling and subjugating. (Shiva, 1997, p. 166-7)

Such arguments seem to posit science, or what is sometimes referred to as ‘Western modern science,’ in opposition to local knowledge, or ‘local science,’ claiming that the proliferation of the former undermines the value and existence of the latter. As such, this

position tends to consider it impossible, amoral or hegemonic to value one over the other. More nuances of these debates are explored throughout the paper, but such a position is not the one adopted in this paper. In order to frame the considerations of science drawn upon here, two dimensions of science are explored below: (1) the internal logic of science and its explanatory power and (2) the relationship between culture and science.

The inner logic of science and its explanatory power. To claim that science is one of many distinct, equally valid and equally powerful ways of knowing the universe on the basis of specific examples of instances of human innovation—for example, detailed and efficient systems of plant classification or effective local means of cleaning teeth—is to make a misstep in logic. The scientific enterprise has made possible countless insights into the working of the physical world, intricate models and theories of its operation, which have allowed for the development of an array of buildings, means of transportation, modes of communication, and many other instances of technology. A certain local classification system may similarly have particular power in accounting for different characteristics of local flora and facilitate their use in a number of technologies related to medicine, nutrition, the arts, and others. Yet, to lump that classification system together with concurrent beliefs about the ‘evil eye,’ for example, and consider it a separate and equal knowledge system that merits protection against the hegemony of ‘Western modern science’ is to take a stance that ultimately harms those populations it seeks to protect. There is something about the scientific enterprise that all inhabitants of the planet deserve access to, both in terms of the body of knowledge it has been able to generate so far, and the characteristics of the process by which that knowledge has been generated. This sec-

tion seeks to identify some characteristics of that process in order to frame thinking about what science is. In doing so, it draws briefly from the field of the philosophy of science.

Before turning to that question, though, it is worth noting that, in addition to the mistake of equating science and a composite of traditional knowledge, practices and beliefs, it is equally limiting and erroneous to identify science as the only means of meaningfully investigating and knowing the universe. For example, artistic expression, a feature of every culture, provides an essential means of capturing and conveying infinite aspects of human existence, and religion offers a means of exploring and understanding less tangible aspects of human reality, such as the purpose of life and the nature of the relationship of human beings to one another and the universe. That science education has been selected as the focus of the paper is not intended to belittle the contributions of other equally necessary dimensions of education and their contributions to development. To orient the discussion of science education, however, it is necessary to give some attention to the nature of science.

Key to thinking about science in the context of potential contributions to development and its relationship to local knowledge is a question central in the philosophy of science: what are the distinguishing features of science that contribute to its explanatory power? In the book *What is this Thing Called Science?*, Alan Chalmers (1976) provides a brief overview of the exploration by the philosophy of science of the defining characteristics of science. The argument presented in the book deconstructs simplistic accounts of the scientific method that emphasize observation, experimentation and inductive logic as the distinguishing features of scientific practice. While these are important elements of scientific practice, Chalmers argues, they are not as straightforward and neutral as is

commonly believed. Observation requires previous knowledge to make sense of what is perceived, in much the same way that training is required to be able to make sense of an x-ray image. Experimentation and induction similarly require decision-making on the basis of pre-existing theory.

Beyond these basic internal characteristics of scientific practice, the philosophy of science has sought to describe the nature of science in terms of how it advances. According to Popper (1959), for example, scientific theories cannot be unquestionably proven, but science can be understood as advancing through the creation of theories that are constantly proven wrong, or falsified, and replaced by superior theories. Kuhn (1962) described science as advancing through scientific revolutions that occur in scientific communities. In a scientific revolution, a dominant paradigm begins to show weakness and is ultimately replaced with one able to describe a larger range of phenomenon. Lakatos (1970), a student of Popper, similarly envisioned science as progressing through changing understandings of communities of scientists, but utilizing the notion of a “scientific research programme” he distinguished between different types of changes. According to his theories, a research programme consists of a “hard core” of commitments that cannot be revised or abandoned without forsaking the research programme entirely and a “protective belt” of auxiliary hypotheses that serve to shield the hard core from falsification (Chalmers, 1976). These secondary hypotheses can change rather easily in response to new findings, while attacks on the protective belt eventually give way to the replacement of a whole research programme by another.

This brief examination of the treatment of the nature of science by the philosophy of science, then, highlights some of the tools of scientific practice, including observation,

experimentation, induction, and falsification. It emphasizes how science advances, not only in terms of replacing some theories with others, but occasionally through revolutions that redefine underlying assumptions and appropriate methods as well. These ideas are important to considerations of the role of science in development. The tools of scientific practice identified here are an integral part of what contribute to its explanatory power, and may be drawn upon by various peoples in efforts to contribute to the development of their societies, as can the body of knowledge generated by science. An understanding of science as changing and progressing allows for consideration of the ways that the meaningful participation of all people and cultures might also influence the shape that it takes. This is explored some in the next section.

Science and culture. A number of scholars argue that it is inappropriate to consider science in the singular, and instead insist that what others refer to as science should actually be considered ‘Western modern science’ which exists in distinction and perhaps some conflict with other sciences, such as ‘Islamic science’ and ‘Maori science’. The logic behind such an argument is that (1) ‘Western modern’ science has developed in a particular historical and cultural context, and as such, the characteristics of that science are not universal, but culturally specific, and (2) to speak of a singular science is to subordinate the knowledge and values that come from outside of the Western cultural tradition to those within Western science. It is important, they feel, not to privilege one knowledge system over another, but rather assert the equality and validity of each by referring to each as a distinct science.

There are a number of problems with this argument. For one, it is historically inaccurate and Eurocentric to consider the modern scientific enterprise to have proceeded

solely from European minds. The current state of science is due in no small part to contributions of Islamic, Indian, and Chinese civilizations, among others, as well as the complex interactions of cultures and conditions through systems such as colonialism (Bernal, 1987; Harding, 1998; Sardar, 1989; Tilley, 2011). Nonetheless, for reasons explored elsewhere (e.g. see Diamond, 1997), it is not unreasonable that certain parts of the world would have thus far been able to make larger contributions than others. This does not make the scientific enterprise solely the possession of a particular geographic region (thereby negating the need to assign other regions their own distinct and delineable knowledge systems). Science as it currently stands could, however, be considered more strongly influenced by particular cultures and it is possible that as participation in the scientific enterprise on a large scale is more representative of the human diversity then the state of science may somehow change as well.

Secondly, criticism of scientific hegemony often rests upon a rather simplistic consideration of the relationship between science and values. ‘Western modern science’ is considered to value objectivity, individuality, and analysis, while indigenous knowledge is considered to value contextuality and interconnectedness (Agrawal, 1995; Semali & Kincheloe, 2002). In this regard, it may be beneficial to consider that there are certain values intrinsic to the logic of science and closely tied to its explanatory power. A thorough and precise consideration of what these are is beyond the scope of this paper, but as examples they might include clarity, objectivity, and precision. Yet there are other ways that particular cultural values and worldviews may unnecessarily, and even harmfully, shape scientific practice and content.

For example, in one well-known case, anthropologist Emily Martin (1991) found that explanations of human conception in textbooks and journal articles followed stereotypical gender roles in a sort of “scientific fairy tale” whereby agency and power were attributed to the sperm, who actively “burrow” through the egg, “deliver” genetic code and “activate the developmental program” of the egg, while the egg “passively drifted” or “was swept” along the fallopian tubes (Martin, 1991, p. 489). In other examples, Gilbert (1988) suggests that notions about social relations between elites and the masses influenced debates over the roles of the nucleus and cytoplasm in cell biology, and Barnes and MacKenzie (1979) argue that social class interests influenced methodology debates in the field of statistics. In her ethnographic comparison of high-energy physicists in the United States and Japan, Traweek (1988) identified several examples of institutional differences between the communities of scientists in the two countries, and how these both shaped and were shaped by culture, for example, systems of tenure and the types of lab equipment scientists utilize. Elsewhere C. Megan Urry (2008), herself a physicist, argued that the “chest-beating” and “self-promotion” that characterize the fields of physics and astronomy correlate with an abysmal rate of participation of women in those fields (generally 10 to 15 percent of PhDs awarded in those fields each year). These arguments suggest that both the content of scientific theories and the institutional characteristics of how science occurs can be subject to the influences of culture.

What these examples also illustrate is that aspects of science shaped by culture are not endless. Theories and models of reality are the products of human minds and intellectual communities interacting with a complex, largely external, reality. There are very few, if any, examples of connections between culture and the models and theories of

physics and chemistry. There are some in biology, the most famous being mentioned above, and many in the social sciences. Arguably, all social science theory and research is shaped by the social and cultural lenses of the academics involved. Beyond influence at the level of theory construction, culture seems to influence the social environment and institutional arrangements in which processes of knowledge generation in science take place.

The conception of science invoked here, then, is one that rejects equating it with a particular people or culture. Science is considered a universal human enterprise, one to which a diverse many societies have contributed in helping it reach its current state, but one in which many have also experienced impediments to their involvement. There are a number of elements of science that facilitate its effectiveness in making robust explanations of the physical universe that have led to countless technologies. These include induction, deduction, falsifiability and the progress of science through the work of communities of scientists working on the basis particular frameworks; but it is important to recognize in these elements their limitations, the room for human error, possibilities of an evolving understanding and the refinement of ideas. Among the contributors to the explanatory power of science are particular values, such as clarity, precision, and objectivity, which have demonstrated their importance for the success of the enterprise. While the extent to which particular cultures tend to share these may vary, this, again, does not merit the exclusive association of science with a particular culture. Also important in this framing of science is a clear distinction between science and technology; the investigation of reality and its description in theories and models is an enterprise entirely distinct from the generation of objects and techniques on the basis of that understanding. Tech-

nologies developed through scientific understanding will have embedded values (Sclove, 1995), and these will likely reflect quite closely the culture and values of the societies in which the technology was produced, but they need not be values with any direct relationship to science at all. Finally, the nature of social science, while also part of the scientific enterprise, is considered distinct from the natural sciences, and therefore is largely not included in this consideration of science education for development—except as it relates to this project as an instance of social science research.

Given that the aim of this description is not a decisive treatise on the nature or state of science, the above ideas are not explored in depth, and it is conceded that many details about which particular characteristics of science are key to its success, and which values are essential for its operation and which are not, can be better worked out by others. Yet, what is important for the objectives of this paper is the position that science is of universal value to the diverse societies of humanity, and that there are identifiable elements of science integral to its operation as well as some characteristics of how it is conceptualized and carried out that may evolve over time and vary with context. As a result, such a conception of science denies the need for consideration of multiple ‘sciences,’ each connected to a particular culture or tradition, while also being wary of a vision of science that would seek to impose a particular way of life on others. These ideas are explored in greater depth throughout the length of the paper.

Framing Education

At the time of the proliferation of schools in the 1920s, there was no inquiry into the ways that people learned. Schools were designed around assumptions that seemed to

be common sense: knowledge is a set of facts and procedures that teachers must get into the heads of children; to do this they should start with simple ideas and gradually introduce more complex ones, and then they may test children to see how much of this knowledge has actually stuck in their minds (Sawyer, 2006). In the 1970s an entire field emerged to study the nature of learning, and by the 1990s, consensus had been reached in the field regarding the importance of deeper conceptual understanding, the need to focus on students' experience of learning in addition to teaching, the value of building on prior knowledge and the role of reflection. Two primary threads of thinking about learning have since emerged in the field. One is focused on learning from the perspective of cognition, interested in how the mind works to make representations and solve problems. The other examines learning from a sociocultural perspective, interested in the way the learning environments shape practice and social distribution of knowledge. While these two perspectives can be seen as competing, they can also be envisioned as providing potentially complementary views of the complex processes of learning in different settings. In this light, a brief introduction to each of the two perspectives is provided below, along with a third perspective, equally important to the aims of this paper: critical education.

Cognitive perspectives on learning. Drawing from an interdisciplinary field called cognitive science, those exploring learning from this perspective are interested in what happens in the mind during the learning process. They are concerned with 'knowledge structures' such as concepts, beliefs, facts, procedures and models, and how ideas are represented in the mind (Sawyer, 2006). In one approach to studying learning, researchers focus on the cognitive processes of experts and then consider the matter of learning as trying to transform novices into experts by helping them develop the same

cognitive processes. Within the field of science education, those working from a more cognitive frame of thinking pay attention to aspects of learning such as the conceptual change required for students to transition from erroneous intuitive explanations of observable phenomena to explanations aligned with scientific theories (diSessa, 2006) and the cultivation of model-based reasoning (Lehrer & Schauble, 2006).

Sociocultural perspectives on learning. Sociocultural perspectives on learning focus on the social and cultural influences on an individual's development and behavior. Of great importance in this perspective was Lave and Wenger's (1991) *Situated Learning: Legitimate Peripheral Participation*. The book shifted focus on learning away from cognitive processes to processes of social practice, emphasizing competence developed in practice rather than consideration of possessions stored in the mind. From this perspective, learning requires active participation in the world. Individuals are considered members of several communities of practice, where they and others are mutually engaged in a joint enterprise, drawing on a shared repertoire of routines, tools, vocabulary, and symbols (Wenger, 1999). Early participation in the practices of the community is peripheral but legitimate, then gradually individuals advance toward fuller, more central, participation (Lave & Wenger, 1991). What is learned in this way includes both the information and concepts of knowledge and the skills and abilities of practice. A number of researchers have drawn upon this perspective to look at learning in out-of-school settings (e.g. Ball & Heath, 1993; Nasir & Cooks, 2009), and the implications of such learning for classroom learning (e.g. Nasir, 2002). In science education, such a perspective has led to interest in exploring the relationship of identity to science learning (e.g. Roth & Tobin, 2007; Brickhouse & Lowery, 2000), the role of previous knowledge and home culture

(e.g. Moll, Amanti, Neff, & Gonzalez, 1992), and considerations of agency (e.g. Roth & Calabrese Barton, 2004), among other topics.

Critical perspectives on learning. Complementary to either of the two perspectives on learning, particularly the latter, is the critical perspective. Such a view traces back to Paolo Freire, and in particular his well-known book *Pedagogy of the Oppressed*. In this book, Freire (1970) proposed a “liberating” form of education that poses to students the problems of their relations with the world as the primary vehicle of learning; collective dialogue is a means to better understand these problems and reflect on solutions. Through dialogue, individuals name the world with the intention of changing it through praxis—a combination of reflection and action for transformation. In this sense, critical pedagogy—an approach to teaching and learning that has developed in Freire’s wake—involves an examination of social forces and conditions that lead to injustice with the aim of becoming an active agent in social transformation. With Freire, this has been associated with conscientization, developing consciousness.

While Freire’s (1970) theories developed in the context of his own efforts around adult literacy in Brazil, his approach holds in high regard the systematic inquiry and related habits of mind that are often associated with science education. He writes of his early work in Brazil:

The education our situation demanded would enable men to discuss courageously the problems of their context—and to intervene in that context; it would warn men of the dangers of the time and offer them the confidence and the strength to confront those dangers instead of surrendering their sense of self through submission to the decisions of others. By predisposing men to reevaluate constantly, to analyze “findings,” to adopt scientific methods and processes, and to perceive themselves in dialectical relationship with their social reality, that education could help men to assume an increasingly critical attitude toward the world and so to transform it. (Freire, 1970, p. 30)

Though Freire chose to focus on literacy, in the above passage he makes clear the value of utilizing scientific processes and methods to investigate social reality in order to transform it, as long as in doing so, they recognize their own dialectic, interconnected relationship with that reality. His notions of education hold great potential for shaping science education towards the goal of students contributing to community change.

Freire and the field of critical pedagogy that sprouted up behind him have been taken up in science education in a number of ways. Some, such as Dos Santos (2008), aim for a particularly straightforward application of the same approaches used by Freire, changing only the content of discussion from sociopolitical issues to socioscientific issues, such as urban garbage and children working in landfills. Such an approach does not seem to dedicate much attention to the ways in which scientific knowledge and practice might contribute to Freire's broader aims of liberation. Others, such as Roth and Calabrese Barton (e.g. Calabrese Barton, 2003; Roth & Calabrese Barton, 2004), consider a critical stance to be crucial in the development of scientific literacy, which should imply being able to use scientific content and scientific thinking for bettering individual and collective conditions. This latter perspective is explored in more depth in various places throughout the paper.

Conceptions of learning and education drawn upon here, then, find value and insight in each of these three perspectives. There is an important social and cultural dimension to learning. It is not the task of isolated individuals but takes place in communities. And the nature of the activities undertaken in those communities—the role that each member, teacher and student, takes up, the meaning and value assigned to different actions and attitudes, the assumptions and habits that go unquestioned—these are key in

shaping what is learned and what is done with it. Such a perspective is central to the exploration of ideas in this paper. At the same time, to consider learning processes exclusively from social and cultural perspectives is to belittle the ways in which a particular understanding and mental representations do influence individual decisions and actions, as well as the value of learning about something independent of its application to practice. Cognition has received much less attention in this particular study, given the topic of interest here, but not with the intention of discarding its value. Meanwhile, education as a means of shifting understanding in a way that opens up possibilities for acting on the world is key to the view of education in this paper, as discussed in more detail in the next section.

Nevertheless, of the various theories prevalent in education research, this study draws most prominently from sociocultural theory. Specific articulations of the theory will be explored in greater depth in the chapters that follow, as they set the stage for particular dimensions of the inquiry. In particular, questions of the relationship between the meaning forged in communities of practice and the agency of members of that community runs throughout the next three chapters.

Science Education as a Means of Social Transformation

The above-mentioned perspectives on science, development, and education have particular implications for the way that science education is framed. These are explored in this section. It is perhaps useful to begin by locating the vision of science education pursued here in the context of the diverse ways it has been conceptualized in the last several decades. DeBoer's (2000) review of the history of science education identified nine

goals of science education that have been present to different extents at various moments in history: (1) teaching about science as a force in the modern world; (2) preparing students for work in a world where science and technology play an important role; (3) teaching about science in its direct application to everyday life; (4) shaping informed citizens who can vote responsibly and influence science-related policies; (5) teaching science as a particular methodological approach to examining the natural world; (6) enhancing the ability to understand science reports and discussions from the popular media (7) developing an appreciation for the aesthetic appeal of the workings of nature; (8) preparing citizens who are sympathetic to science and willing to make use of its expertise; and (9) understanding the nature of technology and its relationship to science.

At first glance, these goals appear to contribute primarily to the maintenance of the status quo for the role of science in society. They seem to suggest that students should be taught to be sympathetic to science and to defer to its expertise. They seek to equip students with the knowledge and skills that will help them acclimate themselves to the existing role of science and technology in their workplaces, their political system and their everyday lives. Such visions of science education would be in conflict with the notions of development, science, and education articulated previously. However, many of these same goals can be directed towards aims of social change. Educational programs can either be conceived as developing citizens who participate in the social system as it stands or as developing citizens who seek to transform the world around them (Westheimer & Kahne, 2004). Within the latter perspective, students can learn a scientific approach to examining the world and use that approach to address questions that break with those typically found in science or the society around them. They can develop an under-

standing of technology that allows them to be more discerning in their selection of appropriate technologies. The appreciation for the aesthetic appeal of the workings of nature can complement and reinforce local traditions typically cast as impediments to scientific knowledge. The direction that these nine objectives of science education take depends on the visions of science, science education, and the role of science in society that they adopt.

Notions of science education as playing a role in social change are increasingly common and this paper intends to engage in thoughtful dialogue with those perspectives. In one clear example, coming from the introduction to a special issue of the *Journal of Research in Science Teaching (JRST)*, a major science education journal, Kyle (1999) lays out the ways in which science education may contribute to social transformation, much of which is coherent with the conceptions articulated in this paper. He argues that the mission of all education, including science education, should be connected to social justice, “fostering critical and participatory democracy, enabling students to recognize that the world that is being presented to them is in fact a world that is being made—it is changing constantly—thus, for this reason, it can be changed, it can be transformed, and it can be reinvented” (Kyle, 1999, p. 256). The science education that Kyle envisions also considers scientific knowledge subject to change and emphasizes the importance of focusing on the whole rather than the parts in the study of the universe. Kyle distinguishes his vision of science education from common contemporary approaches by placing it in the context of collective human action toward social change:

Seldom does an education in science focus upon action, beliefs, or interactions, all in the context of striving to change, transform, and reinvent the world in an effort to create the future. The focus of an education in science ought to be upon an education that fosters learners’ ability to work collec-

tively toward a better society. Such a focus would be in stark contrast to the ways in which learners come to know science through their science education experiences today. The science that most learners have experienced actually serves to disenfranchise learners from coming to know the world and the universe. The science education that most have experienced is bound by disciplines and offers the impression of a static world. (Kyle, 1999, p. 257)

Such a vision of science education, Kyle hopes, will also contribute to addressing the inequities in the social distribution of knowledge as well as the damage caused by links between Western science and technology and “capitalistic overindulgence and consumerism” which have “brought the world to the brink of destruction” (Kyle, 1999, p. 260).

In the JRST special issue dedicated to ‘science education in developing countries,’ the articles following Kyle’s editorial introduction highlighted major issues faced by educators and learners in parts of the world designated as ‘developing.’ Gray (1999), in a second editorial piece, examined factors contributing to a steady decline in the quality of science education in these parts of the world, noting a tendency in science curriculum around the world to follow Western trends and limitations in access to resources. Aikenhead and Jegede (1999) provided an account of how students move between their everyday-life world and the world of school science, and the ways that they handle cognitive dissonance between the two. Drawing from interviews with three village elders and fifteen high school students in a South Pacific country, Waldrip and Taylor (1999) explored the destruction caused by processes of enculturation, in which a ‘Western scientific worldview’ has been adopted with little consideration for traditional culture and beliefs. Akatugba and Wallace (1999) looked at the relationship between culture and proportional reasoning in six high school physics students in Nigeria. Dlodlo (1999) introduced potential means of developing a modern scientific vocabulary in African languages, using physics in Nguni, in particular. Shumba (1999) looked at contradictions

between cultural practices in Zimbabwe that encourage children to respect the authority and wisdom of elders, considering the asking of questions of be a sign of rudeness, and pedagogical approaches that value curiosity as expressed in acts of questioning. Rogan and Gray (1999) examine the work of a nongovernmental organization in reconceptualizing science education in South Africa to confront authoritarian practices. And Dzama and Osborne (1999) review literature and draw on an empirical study in Malawi to argue that poor performance in science in countries such as Malawi should be attributed to an absence of vocational incentives rather than the typical cultural explanations. In other words, in this special issue a rich tapestry emerges of the challenges in creating an equitable approach to science education for development.

This overview of the special issue of such a well-regarded journal highlights a number of the major ways in which the question of science education for development has been taken up in the literature. While none of them explored the more political position of Kyle (1999), who advocates for science education for social transformation, they identify a number of arenas in which the implications of Kyle's vision would have to be worked out: in the interaction of science teaching and local culture, in questions of language, and in connection to other social conditions including job opportunities and access to resources. The research in this paper positions itself in dialogue with studies undertaken from this point of view. It holds closely to Kyle's (1999) vision of science education for social justice and explores how some of the issues raised by these authors, particularly in their concern for the relationship between science and local knowledge and practice, play out in the context of an educational program aimed at capacity-building for social change.

Science, Local Knowledge, and Agency in Science Education for Development

In laying out an approach for social science research distinct from the natural sciences, and perhaps more beneficial to human societies, Flyvbjerg (2001) suggests that the social sciences take a moral stance and address four questions through research: Where are we going? Who gains and who loses, by which mechanisms of power? Is this desirable? What should be done? These questions are taken here as the starting point of an exploration into science education for development, ultimately suggesting potentially beneficial paths of inquiry.

Where are we going in science education for development? Using literature on science education and development on the African continent as a concrete example, those who are in favor of the development enterprise and those who are against, both agree that trends are less than encouraging. Those that consider science education a potentially important factor in the social and economic progress of a nation have found that current strategies fall short of expectations, as students are under-performing on tests and university-training in science has failed to yield the sort of economic benefits found in countries such as India and South Korea (e.g. Jegede, 1997; Savage & Naido, 2003; Zymelan, 1990). What they see is low quality education, due to lack of resources or cultural dissonance. Those in an alternate camp consider science education for development to be contributing to the displacement of local values and practices, and generally part of globalization trends that are fueling greater economic disparities and social homogeneity (e.g. Zaoual, 1997).

Who gains and who loses in science education for development, by which mechanisms of power? These two camps would likely agree that science education is benefit-

ting most those experiencing the highest quality education, often those with the greatest access to material resources and economic opportunities. Trends indicate that the richer are getting richer and the poor are getting poorer (Campfens, 1997), and while science education may not be the largest contributing factor, it takes place in this context and seems to draw from and contribute to the same trends. Critics would characterize the means by which some gain and others lose in the study of science as hegemonic; they would suggest that those whose culture is most similar to what they deem the culture of science benefit most, and those whose culture differs greatly lose the most (e.g. Alvares, 1992). Even many of those who would not consider the study of science hegemonic attribute the failure of science education to cultural dissonance (e.g. Aikenhead & Jegede, 1999), while others look at access to resources and structural factors (e.g. Gray, 1999; Ogunniyi, 1996).

Is this desirable? What should be done? This study is undertaken from the premise that the way forward on any social issue is gradually charted as groups of individuals draw from existing human knowledge and make their best attempt to respond to the issue in a given local context in a reflective approach that is modified and refined along the way. It is in interacting with social reality and trying to shape it positively that one gains valuable insights into it. As different efforts—be they educational efforts, policy efforts, or others—are explored through research and action, and they are put into conversation with one another, deeper and deeper insights into the workings of social reality can be generated. The implication is that through experience and reflection, action and research, more desirable options can be charted. In seeking to answer the questions, ‘What should be done in science education for development? What can be done?’, a single promising

case has been identified here for in-depth exploration. The objective is not to promote a single program as a panacea, but rather to see what some of these issues look like in the workings of that case, in the actions and perceptions of students and teachers in the program.

The selected case, the Preparation for Social Action (PSA) program, was developed by an organization mentioned in the report of the UN Millennium Project task force cited at the beginning of this chapter. While the report itself focuses on science training for the specific purposes of university research and science and technology business, the description of FUNDAEC's work in the report highlighted its emphasis on "learn[ing] about how to involve populations in the process of knowledge generation in pursuit of greater well-being" (UN Report, 2005, p. 98). For reasons addressed in the next section, the case of the PSA program in Zambia seems to hold particular promise for exploring the themes of science education, local knowledge, and community development.

The matter of agency, while its import to the themes of this study is taken up in greater depth in the next chapter, is crucial to the discussion of science and local knowledge because it shifts conversation away from questions of learning for the sake of knowing to learning for the sake of doing. The benefits of learning are framed around enhanced capacity to act. It is this construct that allows for an inquiry into the link between learning and development. While literature on science education and development seem leave a black box in between the two, this study seeks to open up that box to understand by what specific means the teaching and learning of science can lead to improvements in the individual and collective lives of students and their communities.

Specifically, then, this study takes up the case of the PSA program in Zambia to explore questions such as the following: In what ways, if any, do students benefit from their study of science in PSA? How are they using what they have learned outside of the classroom? And how does this contribute to some sort of development? These questions set the stage for deeper explorations of rooted in sociocultural theory, questions such as: In what way does meaning shape agency? How do students navigate the science they learn in the program and local knowledge? The conceptions of knowledge and science woven throughout students' comments and actions are teased apart towards these ends, in hopes of casting debates around science and local knowledge in new light.

Introduction to the Case: The Preparation for Social Action Program in Zambia

As a means of examining some of the aforementioned issues, this study takes up the case of the Preparation for Social Action (PSA) program as offered in Zambia. The sub-sections that follow provide an introduction to the case, identifying in the process the many reasons that make this case one of particular interest for the subject at hand. Zambia in itself is an interesting setting in which to think about development, as a country once succeeding according to traditional conceptions of development. Its education system and educational history is comparable to many other nations in the region. The PSA program, which was developed in Colombia, began as a small effort in Zambia in 2008, only a few years before this study took place, with an approach focused on learning about education for development in that context. Of the places offering PSA at the time of the study, it was one most interested in the science component of the program.

The Background: Education and Development in Zambia

Zambia is a landlocked country in southern Africa, bordered by the Democratic Republic of the Congo, Tanzania, Malawi, Mozambique, Botswana, Namibia, and Angola. It is a low-density nation. According to the 2010 census there were just over thirteen million people spread over more than 750,000 square kilometers, roughly 17.3 people per square kilometer. The weather is moderate, divided into three regular seasons: the rainy season (November to April), the dry season (May to August), and the hot season (September to November). With plenty of land and appropriate weather and rainfall, agriculture is an important part of both the formal economy in Zambia and informal sources of livelihood among much of the population. Yet, more attractive to the global economy has been the nation's subterranean resources, particularly copper. This role in the global market has been central to both the country's self-perception—the beloved national soccer team is known as *Chipolopolo*, the copper bullets—and social and economic conditions over the past several decades.

Copper was first discovered in the region towards the end of the 19th century, when Zambia was considered a colony of the British Empire known as Northern Rhodesia. It was concentrated in the northern part of the central region, in the province now known as the Copperbelt. With the establishment of a number of copper mines, copper became the region's principal export. A number of towns sprung up in the Copperbelt and along a major highway connecting that region to the colonial-era capital of Livingston in the south. Migration to these towns for mining-related work eventually led Zambia to become one of the most highly urbanized countries in sub-Saharan Africa, with 40% of its population currently in urban centers (UNESCO Institute for Statistics, 2014).

According to Ferguson (1999), the growth of the mining industry in the first two-thirds of the twentieth century held for the Zambian people the promise wealth and modernization. He described:

In the mid-1960s, everyone knew, Africa was “emerging.” And no place was emerging faster or more hopefully than Zambia, the newly independent nation that had previously been known as Northern Rhodesia. The initiation of large-scale copper mining in the late 1920s had set off a burst of industrial development that had utterly transformed the country; by the time of Independence in 1964, that industrial growth seemed sure to propel the new nation rapidly along the path of what was called “modernization.” From being a purely agricultural territory at the time of its takeover by Cecil Rhodes’s British South Africa Company in the 1890s, the modern nation-state of Zambia had by 1969 arrived at an urban population of over 1 million (nearly 30 percent of the population), with total waged employment of over 750,000 (of a total population of just over 4 million) (Zambia 1973, 1:1), and a vibrant industrial economy that made it one of the richest and most promising of the new African states. (Ferguson, 1999, p. 1-2)

By the late 1960s, the nation was considered a ‘middle-income country’ with a gross domestic product (GDP) that was not only one of the highest in Africa, but also significantly higher than such ‘up-and-comers’ as Brazil, Malaysia, South Korea, and Turkey (Ferguson, 1999).

Yet, the 1970s proved a decade of a turn in fortune for the country. The buying power of copper in the global market sank, the rising price of oil made it more expensive to transport the metal across the port-less nation, copper production in the country declined, the nation took out large, unfavorable loans from the International Monetary Fund and the World Bank, and later applied structural adjustment policies limiting public spending as a result of those loans. Such changes had drastic effects on poverty in the region. Ferguson described:

Between the declining mining economy and the IMF measures to reduce urban consumption, the lives of the Copperbelt’s inhabitants have been “adjusted” to the point where hunger and malnutrition have become com-

monplace. The World Bank itself reports that the prevalence of urban poverty in Zambia increased from 4 percent in 1975 to just under 50 percent in 1994 (World Bank, 1996). (Ferguson, 1999, p. 10).

Since then, Zambia has been considered a low-income country, whose measurements of GDP, poverty, public spending match others in the region.

The economic changes in Zambia have been closely linked to political circumstances. Zambia achieved independence from the British Empire on October 23, 1964. For over twenty-five years, the country was governed by a single president, Kenneth Kaunda with a single party, the United National Independence Party (UNIP). Economic policies pursued under this party had a socialist tone, with nationalized companies and a centrally planned economy (Shizha & Abdi, 2005). In 1990, as economic conditions declined, riots accelerated and a coup was attempted. The following year Kaunda agreed to multiparty elections and his party lost to the Movement for Multiparty Democracy (MMD). That year saw the privatization of many national companies and the beginning of sector-focused investment instead of central economic planning. In the twenty years that followed, elected presidents all hailed from the MMD party, until Michael Sata, candidate of the Patriotic Front, won in a peaceful election in 2011, during my stay in Zambia. The country has seen some economic growth in the past several years, enough to cause it to pass the threshold of \$1,005 in gross national income per person per year and therefore be reclassified by the World Bank as a lower middle income country in 2011 (Kenny & Sumner, 2011). Yet, the country is still faced with challenges of chronic malnutrition (45.4 percent) and HIV prevalence (12.7 percent, ranking it 7th in the world) (World Food Programme, 2014).

Historically, Zambia has seen minimal internal conflict. This is perhaps due both to demographic make up and to purposeful actions of the government. The population is 99% constituted by people of African descent and primarily Christian in religious belief. Ninety percent of Zambians belong to nine major ethnolinguistic groups: Nyanja-Chewa, Bemba, Tonga, Tumbuka, Lunda, Luvale, Kaonde, Nkoya, and Lozi. These are largely distributed in particular regions of the country, though in the capital and in the Copperbelt there is a great diversity of ethnicities. In these areas, then, most people speak one of the two largest local languages, Nyanja and Bemba. The official language of the nation is English.

Education in Zambia. The political context has had important implications for education in the nation. In colonial times, schools were primarily run by churches and education was available only to a small number of Africans, who were for the most part members of those particular congregations. Arguably, the school served as a means for conversion to Christianity (Shizha & Abdi, 2005). During later colonial times, a partnership was formed between the Church and the state. The colonial government's interest in education was to have a few African workers for administration purposes while the majority of the people remained unschooled and working on the land of commercial white farmers.

Soon after independence, a government policy, the 1966 Education Act, placed education completely under the control of the state, giving the national government responsibility to manage the content, set the calendar, and even appoint staff and determine the admission of students (Shizha & Abdi, 2005). This made the education system highly centralized and bureaucratic, and caused the Catholic Church to hand over all of its pri-

mary schools. The post-independence government also sought to expand education to reach much larger numbers than were educated during colonial times. According to Colson (1999), this was a means of both fueling economic growth in the nation through the development of human resources and legitimizing the new government's fragile position through popular support.

Kaunda specifically was interested in education as a means of promoting an egalitarianism contrary to the system of hierarchy prized by colonialism. He called for serious reforms to the education system in service to the eradication of poverty in Zambia and the promotion of economic growth. His proposal, *Education for Development*, though, was never implemented, and was superseded instead by quite contrary policy proposal, *Educational Reform*, which offered continued support to the highly selective, credentialist and academic-oriented education (Shizha & Abdi, 2005). At the same time, the economic downturn of the 1970s and 1980s limited the resources available for education, thus resulting in diminished quality and participation. The structural adjustment policies that followed worsened the situation, limiting possibilities for public spending. While during that time the government aligned itself with worldwide movements encouraging education for all, it ultimately only supported such efforts through largely symbolic actions—signing international treaties, holding national conferences and creating praiseworthy goals for universal education and gender equity in education (ibid).

In 1996, the national policy *Educating Our Future* established a new framework for the national education system, defining basic education as grades 1 through 9, setting a goal of universal education by 2005, decentralizing the education system and encouraging collaboration with private organizations, religious bodies, and communities to extend

education opportunities (Shizha & Abdi, 2005). In 2002, the government announced a return to the policy of free basic education for the first seven years of schooling (Shizha & Abdi, 2010).

Currently, the education system in Zambia is divided as follows: grades 1 to 7 are considered primary school, grades 8 to 9 are considered lower secondary school, and grades 10 to 12 are considered upper secondary school. In order to pass between these three levels, students must pass a comprehensive exam at the end of grade 7 and at the end of grade 9. At the end of grade 12, students sit for the school certificate examination and must pass six tests, in the areas of English language, other languages, social sciences, natural sciences, mathematics, the arts, or technical and commercial topics (Examinations Council of Zambia, 2014). There are over thirty types of such tests offered by the state, though the ones offered at a particular school will vary. In 2009, Zambia had a primary completion rate of 87 percent, a lower secondary completion rate of 65 percent, and an upper secondary completion rate of 31 percent (Majgaard & Mingat, 2012). Zambia has a particularly high completion rate in Africa for its upper secondary education—only four countries, most of whom have much higher economic measurements, have higher levels of high school completion. Perhaps this can be attributed to the nation's high levels of urban population. Meanwhile, only 136 for every 100,000 Zambians continue on to higher education, one of the lowest rates in sub-Saharan Africa.

At the same time, public spending on education is quite low in comparison to other countries in Africa with similar income levels. In 2005, Zambia spent 2.8 per cent of its GDP on education, compared to an average of 4.3 per cent across African countries labeled as 'low-income' (Majgaard & Mingat, 2012). Some research seems to indicate

that formal education in Zambia is largely perceived as a means to progress economically through formal employment (Motschilnig, 2011). Yet, in 2003, only 15 per cent of those considered employed worked in the formal sector (Majgaard & Mingat, 2012). Serpell (1993) conducted a study from 1974 to 1988 focused on the anticipated and actual outcomes of schooling on a population of about fifty boys and girls in a Chewa community in Zambia. His findings indicated that students and members of the community expect schooling to lead to economic progress through the acquisition of jobs. This, he noted, creates contradiction within the education for all ideals of the state, because there simply are not enough paid employment opportunities. Jensen and Nielsen's (1997) study found both economic and social factors shape why a sample of Zambian parents chose whether to send their children to school or work; with regard to the former type of factors, the study found that many households simply could not afford schooling because the net return to the investment in human capital was too low in comparison to the high price of schooling.

English is the official language of both primary and secondary level instruction in Zambia. Local languages are used to supplement and further clarify English explanations (Mostchilnig, 2011). Many children are not familiar with English prior to starting school, and in urban areas, where speakers of diverse local languages live close together, it may be that even the supplemental language is not the children's mother tongue. Language, then, is a key factor shaping students' educational experiences.

With this brief introduction to the major social, political, and economic conditions in Zambia, it is now appropriate to examine the two dimensions of education in the country that are particularly relevant the line of inquiry of this study: the role of local

knowledge in Zambian education, and the nature of science education in the country. For each topic, available literature is limited. But a few small studies carried out by graduate students at Zambian universities and abroad give some insights into these issues in the region.

Local knowledge in Zambian education. Banda (2008) prefaced his investigation into possibilities of hybridization between formal school curriculum and the indigenous knowledge of the Chewa people in Zambia with accounts of his own personal experiences entering formal schooling as a young Chewa boy in a rural part of the country. He explained, “my parents made it clear to me that I needed to go to school if I were to find a job and look after them and myself in the future” (Banda, 2008, p. 11). While this explanation echoes those perceptions of the importance of education found in other research in Zambia (e.g. Motschilnig, 2011), Banda reported that he found it confusing because he saw that schoolgoers his village were actually economically worse off than those who spent those years watching others’ cows. He described his experiences in school in terms of contradictions between his home and school lives, saying:

My struggle began when I was told I had to stand when talking my teachers. This was a contradiction because when in the community, kneeling was the sign of respect and standing when talking to elders was a sign of rudeness. (Banda, 2008, p. 12)

To this he added other contradictions: he was punished for speaking in his mother tongue, which was called “primitive”; he had to ask for permission in English to use the bathroom while in his community the *only* time you disappear without explanation is to “answer the call of nature”; in the community, quietly looking down and listening to an elder speak are ways of showing respect, while the teacher considered those characteristics the mark of an unengaged child, and expected behavior the Chewa considered rude, such as

asking questions; though his people had a saying that wealth is in the soil, signifying a high importance on agriculture, at school he was surprised to find it was an optional subject and an activity often used for punishment. While it is important to recognize that these are the accounts of one person offered as an introduction to a paper valuing local knowledge, they bring complexity to the discussions of the role of culture in science learning. They illustrate how classroom protocols, insignificant to the learning process itself, can mark a rupture between home life and school life. They show the challenges present when home values and school values seem to be in opposition. It is worth noting that Banda does not hint at his age, and it is therefore unclear whether he attended primary school in the 1970s, 1980s, or 1990s. It is therefore impossible to estimate how much schooling may have changed since then, particularly the tendency he notes that everything associated with African culture as backward.¹

In recent years, the Zambian Ministry of Education has made an effort to incorporate a localized element of the curriculum into primary education under an area called ‘community studies’. The Ministry describes the purpose of such an area of learning as “imparting knowledge, skills, positive attitudes and values to the learners within a locality for individual and community sustainability” (Ministry of Education, 2005, p. 11). It is expected by the Ministry that each local community participate in the planning, development and implementation of such local curriculum, relevant to their local context. They should teach activities common in the area, such as handcrafts, fishing, bee-keeping, cattle-rearing or gardening. In places where this initiative has actually been pursued, teachers aim to collaborate with experienced community members, but challenges

¹ He describes: “There is still a widely held view that anything associated with African culture and

arise in finding people who will actually come (Motschilnig, 2011). Similarly undermining support for such an effort were, in some cases, a desire on the part of parents for school to impart the kind of academic knowledge that was considered to raise status, a question on the part of teachers as to how much time to dedicate to something not tested on the school examinations, and a lack of adequate tools and materials. More fundamentally, researchers examining the application of the community studies dimension of school found that in practice they focused on the development of particular skills over the appreciation of local knowledge, values, and worldview (Kieft, 2009; Motschilnig, 2011). Meanwhile, Motschilnig (2011) described that parents, grandparents and guardians considered passing down everyday skills, values and rituals an important part of their own role rather than something to be taught in school. Many considered skills such as pot-making a valuable fallback for gaps in the type of employment for which formal schooling prepares students.

Both Banda (2008) and Motschilnig (2011) referenced three forms of education, varying with regard to their level of formality, that they feel should be considered complementary and reinforcing. There is *formal education*, provided by the government and private government-recognized schools; *non-formal education*, which is organized and semi-structured, but does not fall under the Ministry of Education, such as community schools run by geographic neighborhoods, religious groups and non-profit organizations; *informal education*, by which individuals acquire skills, attitudes, values and understanding from their daily experiences and the educative resources in their environment. The concern of many parents they find is that certain local skills, values, and rituals should rightly form part of informal rather than formal education.

The few available studies regarding local knowledge in Zambian education, then, identify the sort of cultural dissonance prevalent in other education research on the continent (e.g. Akatugba & Wallace, 1999; Jegede, 1997). The Ministry of Education has demonstrated an interest in addressing such concerns through policies that seek to integrate local knowledge into the formal curriculum. So far, though, a number of factors seemed to impede meaningful benefits of such efforts, including the pressure of school examinations and disagreements about which topics should be taught through formal education, non-formal education, and informal education.

Science education in Zambia. Mudenda's (2008) thesis examined the experiences of twelfth grade students taking biology practical exam, a part of the school certificate examination, which determines whether or not students have passed high school and can then continue on to higher studies. As a biology teacher at Kabwe High School, Mudenda investigated his students' experiences with the final exam through individual and focus group interviews, as well as written narratives. In setting up the value of his topic, Mudenda noted that nationwide less than half (48.5 percent in 2002, and 42 percent in 2003) of students who sit for the exam pass it. In Kabwe, the percentages were a bit better, with 69 percent passing in 2002, 55 percent passing in 2003, and 51 percent in 2004. This failure, it seems, could especially be linked to the practical portion of the exam, which called upon students to do applied science work, such as using a thermometer or a microscope, which most students had never experienced before. Mudenda lamented the broader potential impact of such failure, writing, "it was the unprecedented failure rate in school biology that brings wrong to science education and science-related careers," (p. 2). Results of his study suggested that students had little experience with practical aspects of

science learning and certain topics covered by the test prior to the examination. Some elements were introduced only in the weeks just prior to the exam. Furthermore, the testing conditions themselves, including the vigilance of exam moderators and the limited access to certain materials, also had a negative effect on students' reports of their experience. These findings complemented those of Haambokoma (2007), who, looking at the causes of learning difficulties in the study of genetics in Zambian high schools, found the topic was often not covered or discussed quickly and close to the time of exams. These two small studies provide a view of the limited research on science education in Zambia, highlighting challenges to the teaching and learning of science identified across the continent (e.g. Jegede, 1997).

The history of education and development in Zambia has much in common with many other countries in Africa and many other parts of the world. The end of colonialism did not leave the country with a blank slate, but rather with particular structures, patterns of action, and values that could either be maintained or modified. Some of these developed in Europe; some were created in colonies to ensure the subjugation of the majority for the benefit of a few; some were the heritage of a number of distinct but interacting African groups. How Zambia has proceeded since independence is the result of different internal actors, forces, and groups, as well as external forces such as the global market. As with any nation, there exists the question of how Zambia should move forward. What will assist the people of that nation to more and more have the sort of freedoms and opportunities described by Sen (1999) and Nussbaum (2000)? What role can and should education play in this endeavor? To what extent does science education have a contribution to make in this regard?

FUNDAEC and the Preparation for Social Action Program

An exploration into the interplay of science, local knowledge, and agency in science education for development merits the sort of nuanced exploration that an ethnographic case study can provide. The Preparation for Social Action (PSA) program offered by Inshindo Foundation in Zambia offers one valuable case by which the theme can be studied. The program draws upon considerable science content with the aim of educating youth as protagonists of development in their communities.

The historical development of PSA. In the 1970s, *La Fundación para la Aplicación y Enseñanza de las Ciencias* (FUNDAEC, Foundation for the Application and Teaching of the Sciences) was created to channel the efforts of a handful of scientists interested in learning alongside the agrarian population of northern Cauca in Colombia about enriching processes of community life to affect community progress and well-being. A number of lines of action-research, carried out with farmers and youth from these communities, eventually led to the development of educational content that sought to fill a gap in rural secondary education. In Colombia at that time, primary schools were widely spread across urban and rural parts of the country, but those who wished to continue on to secondary school often had to relocate to nearby towns. The *Sistema de Aprendizaje Tutorial* (SAT, Tutorial Learning System) developed into a six-year secondary educational program recognized by the government as equivalent to grades 6-11, all of secondary school, in the Colombian system. The program spread to many parts of Colombia, offered by different municipalities and non-governmental organizations, as well as several other countries in Latin America, reaching tens of thousands of students.

In the early 2000s, interest emerged to have the program available in English-speaking countries in other parts of the world, and in response, the materials were updated and translated. The resulting program was called Preparation for Social Action (PSA). While PSA draws from the same content and pedagogical approach as SAT, it distinguishes itself from its predecessor in that it does not seek government approval for equivalency for formal education, but instead is envisioned to contribute to community processes through non-formal education.

The PSA program can be understood in terms of the interactions of four primary elements: the textbooks, the tutor, the students, and the community. The textbooks are designed in such a way as to carry the primary responsibility for the educational experience. Workbook in style, they were written as a conversation between the students and the author. The tutors, high school graduates selected and trained by the host institution, are responsible for guiding students in the learning process. They are not considered to be arbiters of knowledge, but instead, having studied the same texts prior to the students, they seek to foster a collaborative process of exploration and reflection. The students are individuals who have completed primary school and are interested in either supplementing their current secondary training, making up for secondary schooling that they missed out on, or continuing to study through PSA after completing high school. The geographic community in which students live is also considered an important part of the program. Usually, the program is established in a particular village or neighborhood through collaboration with local leaders, who provide the venue and help to invite students. Once study is underway, many of the activities of the program require interaction with the

community, and students are encouraged to see their study in light of benefits to the community.

The educational approach of PSA conceptualizes the program—the organization of its content and its expected outcomes—in terms of the development of individual and collective capacity. Specifically, the textbooks are designed around the notion of capabilities, identified by FUNDAEC as “the developed capacity to think and act purposefully in a particular sphere of activity” (FUNDAEC, 2005b, p. vii). Not mere skills, capabilities refer to a more complex realm of thought and action, gradually acquired as skills are mastered, relevant information is assimilated, concepts are more deeply understood, and attitudes and spiritual qualities are developed. Specific PSA texts, then, draw from different disciplines of knowledge, and organize content around the development of particular capabilities, such as the capability to classify, capabilities of describing the world with increasing clarity, and the capability to carry out basic arithmetic and apply it to real life situations. In a given text may be found content that draws from different parts of the natural sciences, mathematics, language, the social sciences, and other fields, organized so as to make particular contributions to the development of certain capabilities.

The textbooks are organized by ‘texts,’ each of which consists of two or more ‘units’. The units that make up a text share particular themes and objectives, though they are physically separate from one another in different workbook-style textbooks and are generally not studied one immediately after another. For example, the units “The Heating and Cooling of Matter” and “Growth of a Plant” together make up a text called *Matter*, in which elements of the atomic theory of matter are explored, first in the context of observing processes of heating and cooling in different systems, and then in the context

of observing growth in plants. Some of the materials envisioned for the program are still in development. At the time that research was carried out for this project 18 units had been developed and were in use; a list of all 18 units is found in a chart in the next subsection.

Academic research on the SAT and PSA programs so far has highlighted a few social benefits of the program, including the empowerment of women within the sphere of public life and in their intimate relationships, the development of participants' sense of social responsibility, and the building of trust among participants of the program and between students and the larger community (Honeyman, 2010; Murphy-Graham, 2007; 2010; Murphy-Graham & Lample, 2014). Such studies have focused on the moral and pro-social dimensions of the program; less attention has been afforded to the nature and implications of what is taught from human knowledge, particularly the sciences.

Science education in the program. Science content is woven throughout much of the PSA textbooks; substantial biology, chemistry, and physics content can be found in 12 of the 18 units currently available, nearly two-thirds of the books. For example, language texts aimed the development of capabilities necessary to describe the world with increasing clarity discuss general and specific properties matter, the concept of change in a system, and the workings of various systems of the human body. Technology textbooks draw from agricultural science, and those books described as developing capabilities related to service draw on science related to environmental protection and human health. The table below provides an overview of science content in the PSA program.

Table 1. Science Content in PSA Texts

Textbook	Science concepts/topics	Science-related activities
<i>Primary Elements of Descriptions</i>		
“Properties”	General properties of matter; phases of matter; specific properties of matter, melting point and boiling point; color, white light; density and hardness	Finding the melting point and boiling point of water, the melting point of wax; using a prism
“Systems and Processes”	Changes in the state of a system; process; systems of the human body, cardiovascular system, gastrointestinal system, nervous system, reproductive system; cells and tissues	
<i>Dawn of Civilization</i>		
“Transition to Agriculture”	Genetics, chromosomes, genes	
“Sumer”		
<i>Basic Arithmetic</i>		
“Classification”	Species, genus, family, order, class, phylum, kingdom; mutualism, commensalism, parasitism; evolution	Classifying local plants
“Numerical Statements”	Measurement; fundamental units of measurement	
“Addition and Subtraction”		
“Multiplication and Division”		
<i>Fractions and Their Applications</i>		
“Fractions”	Prevalence and incidence of disease	
<i>Matter</i>		
“Heating and Cooling of Matter”	Observation; temperature; heat; force; pressure; change of phase; particles; models and theories	Measuring temperatures with a thermometer; measuring heat with a calorimeter; building models of matter in three phases
“Growth of a Plant”	Characteristics of living things; seed structure; structure and growth of a root; cells; substances; mixtures and compounds; compounds and elements; chemical reactions; at-	Using a microscope; observing germinating seeds; observing and experimenting with roots; observing the cross-section of a root in microscope; experiments with substances and

	oms and molecules; chemical equations; model of plant growth	chemical reactions
<i>Energy</i>		
“Transformation and Transfer of Energy”	Work; kinetic energy; gravitational potential energy; elastic potential energy; heat; chemical energy; atomic structure; chemical bonds; electrons	Rolling marbles on an inclined plane (to demonstrate principles of kinetic energy)
<i>Food Production on Small Farms</i>		
“Planting Crops”	Soil horizons; erosion; soil structure; pH; chemical composition of soil; soil biology; seed structure	Talking to farmers about farming tasks; erosion experiment; pH measurements; collecting samples of nutrient deficient plants; collecting organisms in the soil; preparing land
“Diversified High-Efficiency Plots”	Water cycle; biological and physical characteristics of common weeds; entomology; plant diseases	Talking to local farmers about farming tasks, irrigation, polyculture; planning and carrying out a polyculture plot; researching local weeds; examining insects from the field; researching common local plant-eating insects; researching common local plant diseases
<i>Nurturing Young Minds</i>		
“To Describe the World”		
<i>Promoting a Healthy Environment</i>		
“Environmental Issues”	Threshold for air pollution; renewable and non-renewable resources; biodegradable and non-biodegradable waste	Conversations with others about transportation and air pollution; conversations with small & large manufacturers about waste management; researching on waste in the community; project to improve environment
“Ecosystems”	Ecosystem; biotic and abiotic components; food chain; dynamic equilibrium; carbon sequestration; nutrient cycles	Visits to a forest, to a pond and analysis of components of those ecosystems; project to improve a particular ecosystem
<i>Family Health</i>		
“Health and Disease”	Skin diseases; intestinal parasites; bacterial causes of diseases	Interviews with mothers about children’s skin diseases; meeting with friends and neighbors

		about intestinal parasites; research on what people know about diarrhea
--	--	---

From among the 18 units, three are characterized as contributing to the development of the capabilities of a scientist. The introduction for the tutor at the beginning of the unit “The Heating and Cooling of Matter” describes:

The investigation of reality is central to human existence. Every human mind longs to penetrate the mysteries of the universe and find answers for the reasons and causes for things. In this regard, science can be thought of as a dynamic system of knowledge and practice that serves to organize humanity’s collective experience as it strives to understand physical, social, and intellectual reality. Progress depends on the advancement of science and the technology it engenders. A typical scientific textbook will offer students an account of the knowledge that has accumulated in the field and expose them to relevant methods. Yet, if young people are to prove capable of meeting the many challenges that face their communities, it will not be sufficient for them to learn various facts and information taken from traditional branches of science. Accordingly, the textbooks in FUNDAEC’s program “Preparation for Social Action” attempt to go beyond the mere exposition of knowledge to prepare students to approach the investigation of reality in a scientific manner. (FUNDAEC, 2005b)

These sentences frame the perspective of science learning in the PSA program, the implications of which are investigated in this study. The materials envision students as having natural scientific inclinations and see the role of science education as assisting students to approach the investigation of reality scientifically, in order to meet the challenges that face their communities.

While activity in the program often consists of reading from the textbooks aloud in small groups, and discussing ideas, questions, and exercises posed by the text, with the support of a trained tutor, the books also call upon student to carry out more dynamic activities. “Properties,” “Planting Crops,” “The Heating and Cooling of Matter,” and “Growth of a Plant,” all have students carry out small hands-on activities to complement

the ideas of the lesson including measuring the melting point and boiling point of certain substances, simulating processes of erosion, calculating the energy transferred between substances in certain experiments, and observing chemical reactions between certain acids and metals. The units “Classification,” “Planting Crops,” “DHE Plots,” “Environmental Issues,” “Ecosystems,” and “Health and Disease” instruct students to investigate certain science-related phenomena in their local context such as common species of plants, local farming practices, waste management practices in local manufacturing units, and common skin diseases faced by children under five in families they know.

Certain activities of the textbooks also direct students to do things that benefit the community. In “To Describe the World,” participants are guided to teach small groups of preschoolers a series of lessons. In “Environmental Issues,” they are encouraged to raise awareness about issues of waste management. In “Ecosystems,” they are asked to take steps to improve a particular ecosystem around them. And in “Health and Disease,” they are requested to raise awareness about skin diseases affecting small children and parasites. These sorts of activities underscore the primary aims of the program, which is centered on service. Indeed, FUNDAEC itself describes service to the community as “the axis around which it designs curricula and integrates knowledge from different fields of human endeavor” (FUNDAEC, 2006).

Local knowledge in the program. The materials PSA students study also call upon them to draw from knowledge held by others in their region and to generate information themselves about conditions where they live. The chart below provides an overview of the ways local knowledge is woven into the 18 units of the program.

Table 2. Local Knowledge in PSA Texts

Textbook	Activities to Research Local Knowledge or Conditions
<i>Primary Elements of Descriptions</i>	
“Properties”	
“Systems and Processes”	
<i>Dawn of Civilization</i>	
“Transition to Agriculture”	Talk to friends, family and neighbors about local myths and legends, about perceptions regarding the difference between human beings and animals, their perceptions of the importance of plant and animal conservation, and their thoughts about the purpose of existence
“Sumer”	Research a social, political, or economic system in the microregion (such as the transportation or educational system); ask three people what they feel is important in life; research common illnesses and what is known about symptoms, causes, and remedies; research local apprenticeships; research local forms of irrigation
<i>Basic Arithmetic</i>	
“Classification”	Classify local plants
“Numerical Statements”	Research into conditions of the microregion, including major industries, annual rainfall
“Addition and Subtraction”	Visit small businesses in the microregion to learn how they manage their accounting
“Multiplication and Division”	
<i>Fractions and Their Applications</i>	
“Fractions”	Research rates of incidence and prevalence of a particular disease in microregion
<i>Matter</i>	
“Heating and Cooling of Matter”	
“Growth of a Plant”	
<i>Energy</i>	
“Transformation and Transfer of Energy”	
<i>Food Production on Small Farms</i>	
“Planting Crops”	Research how local farmers classify soil and prepare the land
“Diversified High-Efficiency Plots”	Talk to local farmers about farming tasks, watering plants, polyculture; plan and carry out a polyculture plot, growing a mix of crops; research local weeds; examine insects from the field; research common local plant-eating insects; research common local plant diseases
<i>Nurturing Young Minds</i>	
“To Describe the	Ask grandparents in the community about experiences raising

World”	children
<i>Promoting a Healthy Environment</i>	
“Environmental Issues”	Conversations with others about transportation and air pollution; conversations with small & large manufacturers about waste management; research on waste in the community; project to improve environment
“Ecosystems”	Visits to a forest, to a pond and analysis of components of those ecosystems; project to improve a particular ecosystem
<i>Family Health</i>	
“Health and Disease”	Interviews with mothers about children’s skin diseases; meeting with friends and neighbors about intestinal parasites; research on what people know about diarrhea

Twelve of the eighteen units have some sort of activity to research about local conditions and local practices. In these activities, students talk to farmers, small business owners, those working in factories, mothers, and others about their knowledge and practices. They may also visit libraries and local institutions to find out information about local conditions. On other occasions, they collect their own data firsthand, counting the amount of waste in a particular area of land or measuring the temperature and pH level of a local pond. Of the units in the above chart not identified as seeking local knowledge, even several of those—including “Properties”, “Systems and Processes”, “Multiplication and Division”—called on students to describe characteristics of their local conditions from their own knowledge, without necessarily going out to investigate from others, further suggesting the value of local knowledge and personal knowledge.

The PSA program, then, is one in which science content and local knowledge are woven throughout, making rich the opportunities to explore the connection between the two. As an endeavor focused on helping students develop capacity to serve as “promoters of community well-being” in the places where they reside, the study of science, and all learning in the program, aims to contribute to community development. For this reason, the approach to science education found in the PSA program is one particularly apt

for an in-depth exploration of ways in which the learning of science might actually contribute to community development, and the interaction of science and local knowledge and beliefs in that regard. At the time of the study, there were about seven to ten places in the world where the program was being offered, still in its early stages. For reasons discussed in the next subsection, Zambia turned out to be an optimal choice.

Inshindo Foundation and PSA in Zambia

Inshindo Foundation began to offer the PSA program in 2008 in Mwinilunga, a northwestern province of Zambia, and in the capital of Lusaka. Following challenges in Lusaka, the program was moved to Kabwe later that year. The first students from both localities graduated from the program in early 2011. Building from a few decades of efforts in the areas of literacy, health education, and youth empowerment of the William Mmutle Masetlha Foundation, the Inshindo Foundation was established as a separate entity in 2008, specifically with the purpose of offering the PSA program. “Inshindo” in several Zambian languages means “footsteps one hears when people are moving from one place to another.” According to those working at the organization, it implies movement with a purpose and captures the organization’s aims of contributing to the purposeful movement of local populations through educational opportunities.

The Foundation has taken the approach of trying to learn about the program gradually, by beginning with a small number of groups and slowly expanding its capacity to offer to larger numbers. In Kabwe, the first graduation, in early 2011, yielded 37 graduates, with another group of 9 who completed a few months later, during my time there. At the time of my research, toward the end of 2011, there were about 90 students in

Kabwe. And in August 2012, a few months after I left, 39 of them graduated, while the others were still at earlier stages of the program. Several hours north of Kabwe, in Mwinilunga there were similar numbers of students and graduates.

Not all the groups that began, especially initially, were able to complete the program. Over the course of the roughly two and a half years of study in the program, some students move, some find jobs with conflicting schedules, and some leave for other reasons, causing groups to collapse or two groups to merge into one.

Of the handful of institutions offering PSA worldwide at the time of the study, Inshindo Foundation seemed to have paid particular attention to projects and activities connected to the science content of the program, especially as it related to agriculture and environmental protection. When their first groups began the study of those units, the organization held a few meetings with students to explore in depth the sorts of projects they might undertake and to encourage them in their efforts. Several of the projects designed and implemented by these first groups ended up becoming part of the regular rhythm of study of groups that followed, though they are not explicitly mentioned in the textbooks. Such projects include carrying out research on the prevalence of backyard gardens in the local community and then helping neighbors to start their own gardens, and sharing with others the causes of malaria.

The case of the Preparation for Social Action program in Zambia, then, holds special potential for more in depth consideration of science education for development. The country's experiences of education and development during the past fifty years since independence are characteristic of many other countries in the region. They highlight both the success and failure of development centered on participation in the global economy,

as well as struggles to draw from both the Western education system and local knowledge in national policies of science education. The PSA program, though only operating at a very small scale in the country over the period of a few years, is of interest for the aims of this study specifically because of the way it seeks to orient education toward development, drawing from both modern science and local knowledge.

Approach to Research

A Role for the Social Sciences

As suggested above, this study is undertaken from a phronetic approach to social science research. In *Making Social Science Matter*, Flyvbjerg advocates for the social sciences to abandon attempts to operate in the same mode as the natural sciences. “Social science,” he asserts, “never has been, and probably never will be, able to develop the type of explanatory and predictive theory that is the ideal and hallmark of natural science” (Flyvbjerg, 2001, p. 4). Many of those characteristics of science that contribute to the strength of natural science—such as looking for universal rules and patterns, independent of context—undermine the ability of social science to meaningfully capture insights about human activity.

What Flyvbjerg (2001) proposes instead draws from Aristotle’s classification of several types of “intellectual virtues.” Aristotle’s *episteme*, is generally translated as ‘science’ or ‘scientific knowledge’ and refers to the production of knowledge through using analytical rationality to identify universals and principles. *Techne*, translated as ‘art’ and ‘craft,’ concerns the application of technical knowledge and skills, in other

words, “know how.” And *phronesis*, often translated as ‘prudence’ or ‘practical common sense,’ emphasizes practical knowledge and wisdom; it requires experience. Flyvbjerg suggests in this light a phronetic approach for social sciences shaped by value-rational questions, such as: Where are we going? Who gains and who loses, by which mechanisms of power? Is this desirable? What should be done? Such explorations are aimed at both social commentary and, importantly, social action.

In the phronetic approach to social science Flyvbjerg (2001) mentions, case studies take on particular importance, due to his claims that human affairs are necessarily context dependent, and that case studies offer a wealth of details and a close account of real-life situations that allow for a nuanced view of reality. On a given topic, case studies may be selected strategically to yield particular insight into the matter. In this case, given the limited explorations of connections between science education and development, it makes sense to choose a case where the connection between those two is particularly explicit and promising in order to better understand the complexities of what this looks like in practice.

Flyvbjerg (2001) encourages particular attention to values (in the sense of whether the phenomena being examined is appropriate and coherent with the values society should uphold) and power (in the sense of how some are benefitting at the expense of others), with the aim of assigning social science a role in helping societies continue to progress in a desirable manner. The primary questions he identifies would seem to particularly lend themselves to identifying contradictions, flaws, and injustices in social systems. After asking, ‘who gains and who loses, by which mechanisms of power?’, the answer to the question ‘is this desirable?’ would generally need to be ‘no’, unless the previ-

ous question found that everyone gains and no one loses. To seek out and bring to light such contradictions and injustices would seem to be quite a valuable role for social science, one that hopefully would contribute to injustices being addressed through policy and other means. Yet, one might ask whether this sort of critical approach is enough on its own. Is there a sense in which constantly finding flaws in a system might lead to cynicism and a warped view of human beings and human societies primarily in terms of their flaws?

Perhaps, it is the position of this paper, in addition to critical analyses are needed those seeking out and exploring potentially promising efforts, to get a better sense possibilities and relationships. The need for such research is clear in the field of education, for example; it would not make sense to focus only other shortcomings of particular educational practices. At the same time, the cohesion and progress of the science would be hampered if the approach was to identify and celebrate particular techniques as a panacea to the struggles of the education system. There needs somehow to be room to try out approaches, see what insights are generated in those experiences, and allow things to continue to grow and occasionally be modified through experience and reflection. Such an approach would have implications for ethnographic research. The approach undertaken here shares with critical ethnography a commitment to utilize ethnographic methods as part of a contribution to social change and social justice (Carspecken, 1996). Yet, rather than utilize critique as the primary vehicle for change, it seeks to identify and articulate the potential strengths of a nascent program, while also recognizing arising limitations and challenges.

Research Setting

Roughly 138 kilometers, or about two hours travel, north of the capital of Zambia, Kabwe is a small city of approximately 202,000 people (Republic of Zambia Central Statistical Office, 2011). It is the fourth largest city in the country and the capital of the Central province of Zambia. Historically, it has been an important transportation and mining center for the country. The mining and smelting of lead, zinc, and cadmium have been major industries around Kabwe, and as a result the small city has become the locality most affected by heavy metal pollution in a country centered on the mining industry (Yoshinori et al., 2010). In recent years a study by the Blacksmith Institute named Kabwe as one of the ten most polluted places in the world, reporting that levels of lead in children's blood in Kabwe was measured to be on average five to ten times the permissible WHO/EPA maximum of 10 g/dL (The Blacksmith Institute, 2007).

Once the leading lead and zinc mining town in southern Africa, Kabwe fell upon difficult economic conditions when the mines were shut down in 1994, and the Zambia-China Mulungushi Textile company closed some time thereafter. A large number of residents have been left unemployed as a result. Other industries found in the small city include Kabwe Industrial Fabrics Company (KIFCO), the Zambia Railways consortium, small scale mining at the old mine, and civil service (Chitambala, 2013).

The Field Research

In summer 2004, I spent a few days in the mountains of department (province) of Antioquia in Colombia. It took 45-minute rides on the back of motorcycles or in local *chivas* (wooden open-air buses) along the ups and downs of the mountain ranges to reach

small primary schools tucked between slopes and slopes of coffee plants. Here small children met every weekday to learn reading and arithmetic. On the weekends, older kids and adults met there for two full days—teenage girls who helped their mothers around the house during the week, young mothers, young farmers who spent the week caring for coffee crops, and even a few grandparents. On my brief visits, I saw them gather in small groups around their workbooks, helping one another to solve for x in algebra equations, sector out the directions of force with vector diagrams, and calculate the period and amplitude of waves. In informal conversations, students gushed about their appreciation for being able to continue their studies as a part of their lives on the farm, without needing to go into town. The juxtaposition of expansive fields of coffee, heavy rubber boots and machetes, with math and science exercises that I was finding difficult in my senior year of college was one that brought to the fore the question of ‘education for what?’ What kind of education is of use to a person who spends scores of hours each week working in the fields, or washing and cooking for the family? Was the rigorous study of math and science a right of which these individuals had until recently been deprived because of the limited accessibility of secondary education in the region? Was it a luxury superfluous to the necessities of their reality? Or the false promise of system and worldview at odds with the rhythms of their lives?

Such questions informed my interest in science education and education for development as, in the years that followed, I got to know the work of FUNDAEC, whose program I had been visiting in Antioquia, and as I continued my studies in graduate school later on. In framing the exploration of this study then, I returned to the efforts of

FUNDAEC, this time choosing as a subject the Preparation for Social Action program in Zambia.

Field research for this project spanned nine months, from June 2011 to April 2012. Through connections made during a two-year internship with FUNDAEC in 2005-2007, I reached out to Inshindo Foundation. It was decided I would spend nearly a year there, carrying out the research while also assisting with the efforts of the organization to build capacity for local tutor training.

Early in the fieldwork, I spent most days at the primary Inshindo office, participating in all of the activities taking place there: weekly tutor planning and review spaces, monthly tutor reflection spaces, monthly student reflection spaces, tutor trainings, weekly coordinator consultations and periodic coordinator planning and reflection gatherings. These spaces offered the opportunity to become more familiar with the rhythms, patterns of action and discourse among participants of this community of practice—the way tutors spoke of their groups in reflecting on the past week’s activities, the sorts of questions that coordinators used to orient discussions, and the feedback students brought to gatherings. These were spaces where participants at all level spoke about what they were doing to one another, both reflecting on the past and making plans for the future.

More importantly, joining in on these spaces first allowed me to build relationship with tutors, students, and field coordinators of the program, gradually and more naturally, through informal conversations over lunch and as a face that grew familiar across the room at meetings. Having grown up in Israel, lived in a few other countries before Zambia, and previously conducted research in Colombia, I was not unfamiliar with the experience of being a cultural newcomer, someone from a noticeably different background

because of language, habits, or appearance. Kabwe, however, was the first place where visual cues seemed to allow people I met in the street to feel confident drawing conclusions about the purpose of my visit to their country. Either I was a missionary, or someone working for a non-governmental organization (NGO)—someone coming from outside to fix local problems. Building relationships, then, was important to being able to take up the position I saw for myself, someone wishing to learn about and from the experiences of an organization indigenous to the region, alongside participants. It took time to build the sort of mutual understanding that could foster joint exploration. Efforts to do so were not always seamless. For example, in a few interviews conducted with students the first time we met, it felt to me that some described their experiences in the program as if trying to convince a foreign donor to either continue investing in it or make certain changes that they recommended.

Through the relationships that developed at Inshindo, I could speak to tutors about when and how it might be possible to visit groups of students during their study in a manner that would be comfortable. The PSA groups met in community centers, libraries, churches, and clinics in the various townships of Kabwe. I visited seven different PSA groups during their lessons, ultimately deciding to focus visits on two groups in particular with differing characteristics for ongoing visits. One was a large group in a small, more rural part of Kabwe. The group consisted of about ten participants, half of whom were studying in high school at the same time. In conversations with those at Inshindo, it seemed the perception was that there was a certain vitality in the activities of that group; for example, through their initiative, a community center had been built in the community where they lived. The second group was a small one, whose numbers had diminished

over the course of two years. The group had changed tutors three times in that period, due to the personal circumstances of the first two tutors. Both groups were about three months away from completing their studies by the time I left Zambia. The aim in selecting these two groups was to get an in-depth view that captured some diversity of experience. I regularly joined the study and other activities of these groups over the course of about four months, for a total of 40-50 hours of field visits. Roughly twelve of those hours were audio-recorded. Others were captured in notes scribbled in the textbook and detailed field notes after the visits. Outside of regular classroom study, I joined the group for science experiments, gardening, visits to farmers, service projects, and community meetings, among other activities.

Complementary, and perhaps more important than the participant observation, were the interviews with students, tutors and graduates of the PSA program in Kabwe, Zambia. For the most part, these interviews came after months of participating in various spaces, building familiarity and relationships. In total, 56 individuals participated in interviews, including 13 current Kabwe tutors, 24 Kabwe students, individually, in pairs, or in groups, 6 Kabwe graduates of the program (3 of whom were also current tutors, 4 of whom were from the same group), 7 current and former Kabwe coordinators and administrators (4 of whom were former tutors), and 9 students, tutors, and coordinators from Mwinilunga, a second site for the program in the Northwest of the country. The interviews generally lasted one to two hours. They included questions about how the individual(s) became involved with the program and their initial perceptions, about books they enjoyed most or found most helpful, and their perceptions and experiences in studying them. Whenever possible, the textbooks they mentioned were handed to them so that

they might be more specific in their explanations. Later in the interviews, participants were given a small stack of notecards with science-related activities found in the textbook written on them. They were asked to choose a couple that they wanted to describe in more depth, because they were particularly successful and interesting or because they were particularly troublesome. Some respondents additionally described in some depth their experiences growing gardens. In the case of a few research participants, the interview spanned two or three separate conversations.

Among the groups participating in interviews—students, tutors, graduates, coordinators, and other staff—the experience of tutors in the program has been a particularly rich source of insight. Tutors contributed both as educators in the program and as students. Though a simplistic comparison of the PSA program to standard formal education would cast tutors in the role of teachers, tutors actually have much in common with students. They have not received any sort of professional teacher training or certification, and have no answer key or any teacher-specific tools. Their first exposure to the content of program is in a manner very similar to students; groups of tutors receive blank textbooks and study them in consultative sessions with a tutor-trainer. They read, complete the exercises, and carry out the practice activities in much the same way students do. But instead of weekly study, tutors first study the texts during a two-week intensive session. They use their experience in that two-week training to inform the study with their own groups. In this way, there is not much difference between tutors and students of the program. Before becoming involved with the program, they represented much the same pool, with the exception that tutors had to have completed high school, while only some students had completed high school, and others were currently in high school or had

withdrawn before completion. In one case, a tutor explained to me that she had initially started studying in PSA as a student, but left the group when she got a job. Later, when she was no longer working at that job, she found they were looking for tutors for new PSA groups, applied and became a tutor of the program. Like students, tutors expressed in interviews things that they had learned in PSA and ways that they have benefitted from the science studied there. The interviews with tutors, then, engaged them both in terms of their experiences as learners in the program and their experience as educators.

Having previous experience with the PSA program, both as an intern at FUN-DAEC and conducting research about the program in Colombia, allowed me to discuss the program with participants in ways that were not foreign, as a legitimate member of the community of practice in many ways. Furthermore, I had a deep familiarity with the content of the textbooks and other supplementary materials, making it easy to understand references being made to specific activities and concepts of the texts, even if I was not present during the activity itself. It also allowed me to make informed choices about which groups to visit during which texts and activities, so as to get the best sense of the science component of the program in action. At the same time, any position from which an ethnography is undertaken has its particular strengths and limitations. As someone intimately familiar with the program, I had to be extra cautious that I did not map my own vision of the program onto what others were saying. I had to strive for questions that were sincere in their open-endedness and responsive to the comments being made, additionally reflecting my understanding of what they were saying back to them. This, of course, is a requisite for any ethnographic project.

Data analysis is described in further depth in the next three chapters. As an overview of the process, early on data analysis centered on line-by-line coding of interviews, the creation of memos on that basis, and the writing of case studies (Emerson & Fretz, 1995). As particular themes emerged along these lines, additional approaches to data analysis were undertaken, specific to the objectives of each chapter.

Overview of the Next Four Chapters

This study seeks to explore concretely the ways that the teaching and learning of science can contribute to developing capacity for involvement in community development. In aiming to find more explicit connections between these two, it pays particular attention to relationships between meaning and agency, especially, in the interactions of scientific knowledge and local knowledge.

This begins in the second chapter by delving into the concept of agency. Attention to the potential of science teaching and learning to contribute greater capacity to act and exert influence on the world has been a theme of interest for a number of science education researchers. The second chapter builds from constructs they have developed to explore how these might apply in the context of science education for development. It looks to the case of PSA in Zambia to identify specifically what participants become capable of through their study, and ways these inform broader thinking about agency in the context of science learning for development. The result is a refined vision of science agency that will inform explorations in the two chapters that follow.

The third chapter, then, takes up conceptions of knowledge and explores how the notions that participants' invoke in their studies and in related activities shape the ways

they demonstrate science agency. In doing so, it takes up Holland, Skinner, Lachicotte, and Cain's (1998) notion of figured worlds, but rather than focus on the relationship between agency and identity, as Holland et al. and many science education researchers have, the chapter looks at the relationship between agency and other sorts of meaning, specifically meaning around knowledge. It follows the forging of meaning around knowledge in different contexts, spaces of complexity and contradiction, and the ways that these shape science agency.

The fourth chapter examines the findings of the previous two chapters in the context of questions emerging from the literature, as described in this introductory chapter. Specifically, it takes up debates around science and local knowledge in science education and development literature as well as the question of community development.

The last chapter connects these themes back to Flyvbjerg's phronetic social science research.

CHAPTER II

RETHINKING SCIENCE AGENCY

The exploration of science education for development of this paper begins by looking at the connection between science learning and community development. Drawing on the case of PSA in Zambia, it asks, in what ways do participants' experiences of learning science affect the things that they do outside of the classroom? What are the contributions of this science learning to community development? Through attempting to open up what has in some sense been a black box of science education for development, a foundation can be established for thinking about some of the conceptual orientations that shape the benefits of science education and its contribution to development, including conceptions of science and local knowledge.

The construct of “agency”—central to sociological questions regarding the relationship between individuals and social structures, of value to discussions about the ends and means of international development, and heavily referenced in approaches to science education concerned with social justice—is of particular use in articulating a link between science education and development. After a brief review of the concept in relevant literature and the selection of a particular iteration of agency useful for the objectives of this paper, the chapter draws upon participants' own accounts to provide an overview of ways that they consider themselves to be using their science learning for individual and collective benefit. A few cases are then discussed in depth to explore particular manifestations of science-related agency and their contributions to development.

Critical Science Agency for Community Development

Drawing upon 'Agency'

Broadly speaking, the notion of agency emerges in sociological questions regarding the relationship between individual actions and the social structures within which they occur. Can all human behavior be traced back to the influence of social forces and social structures? Or do individuals possess a free will that enables them to chart their own courses? More plausible responses to such questions have identified a middle way where the relationship between agency and structure is a reciprocal one. Giddens, for example, (1979) asserted that individuals' actions are shaped, in both constraining and enabling ways, by social structures, and that at the same time those actions reinforce or reconfigure the social structures that have shaped them. Bourdieu (1977) used the notion of habitus to express similar conceptions. Habitus he considered to be a generative process whereby practices and representations are produced, conditioned by social structures. These practices and their outcomes reciprocally reproduce and reconfigure the habitus. The structure – agency dialectic allows for the possibility of social change, as individual agents take actions that contribute to shaping the habitus or social structures differently. Of note, agency in these examples is posited in contrast to structure, essentially as its opposite. Agency suggests a freedom from the constraints of structure. While the interplay of social structure and individual decision-making is important to framing conversations of social change, the notion of agency employed here is not focused on individual freedom from social influence, but rather about opening up the possibilities for action in a direction that one deems beneficial to one's life. A few instances

of the use of agency in development and science education literature will be of use in clarifying this idea.

In development literature, Amartya Sen's (1999) characterization of development as freedom draws in part on notions of agency. Sen argues that development should be seen as a process of expanding the real freedoms enjoyed by all people. From this perspective, common aims of development, such as growing the gross national product (GNP), industrialization, and social modernization, are displaced and recast as means of expanding the freedoms of members of society. Development, then, must identify and remove sources of unfreedom, such as poverty, political tyranny, poor economic opportunities, and systemic social deprivation. One of the primary reasons for ascribing such importance to individual freedom in the conceptualization of development, according to Sen, is that substantive freedom determines individual initiative and social effectiveness. In other words, "freedom enhances the ability of people to help themselves and also to influence the world, and these matters are central to the process of development" (p. 18). It is this ability to help oneself and influence the world that Sen identifies as agency. Agency on the part of individuals may be exercised in a range of economic, social, and political actions in which they participate, from taking part in the market to involvement in policy-related decision making. Agency as described by Sen is important for purposeful social development.

Within science education, researchers such as Roth and Calabrese Barton have advocated for an approach to science education directed at students' capacity to change their own lives and the circumstances around them. Whereas often science courses are a "means of pushing students into the world of scientists," in this light they are seen as "a

way of helping them cope with their own life worlds” (Roth & Lee, 2004). This type of science education aims to make students literate in the problems framed by their own lives, instead of directing scientific literacy at enabling students to engage in debates framed by science (Calabrese Barton, 2003). Roth and Calabrese Barton (2004) connect this distinction to the notion of agency: “Rather than getting science-related stuff into the heads of children, we want them to expand their agency, the room that they have to maneuver, and the possibilities for acting and thereby and changing their life conditions” (p. 17). Here, then, they characterize agency as expanded room to maneuver, creating greater possibilities for acting and changing their life conditions through these actions.

Reoccurring in the notion of agency across these fields is the idea of the individual’s capacity to act on the world. While numerous social forces and structures influence human behavior, the discussions of agency mentioned here direct attention at the individual’s potential to act in opposition to those forces or somewhat independent of them, rather than becoming a slave to them. In the case of Sen (1999) and Roth and Calabrese Barton (2004), they are particularly interested in the sort of agency that contributes to social change and the pursuit of social justice. In both instances, they value agency dually in its potential contribution to social change and as an end in itself, suggesting that the ability to influence one’s own conditions and those of others is in itself a fulfilling dimension of life. Drawing from these articulations, the notion of agency is taken up here to examine the ways science education can facilitate an enhanced capacity to act on the world, in pursuit of better personal circumstances and social change.

Critical Science Agency

Shortly after the articulations of agency in science education quoted above, the construct of ‘critical science agency’ gained a certain momentum among a small group of science education researchers, primarily Angela Calabrese Barton, Jhumki Basu, and Edna Tan. Their notion of critical science agency forms the basis of explorations of agency in this study and, as such, is explored in some detail in this section.

Critical science agency is perhaps most clearly articulated by Tan and Calabrese Barton in the following passage: “... agency with and in science implies that students use the knowledge, practice, and context of science *to develop their identities, to advance their positions in the world, and/or to alter the world toward what they envision as being more just*” (Calabrese Barton & Tan, 2010, p. 195, italics in original). The construct emphasizes two dimensions of an educational experience. First, it entails the development of a critical mindset, with which students analyze forces in their surroundings and take action that contributes to making the world more socially just. In this regard, it draws directly from critical pedagogy and the work of Freire (1970). Second, it implies the development and use of scientific understanding. In working towards justice, students can use the possibilities afforded by science. Specifically, they can draw upon knowledge that has been generated by communities of scientists, they can utilize the practices of science for themselves, and they can interact with the discipline of science as a context for their efforts.

Critical science agency responds to a particular reading of the state of science education in North America. Educational research has identified distressing trends regarding who tends to take on higher studies in science and performance in science classes by

gender and ethnicity (e.g. Norman, Ault, Bentz, & Meskimen, 2001; Tindall & Hamil, 2004;). Attributing such disparities to overlooked differences at the level of culture, several in the field have recommended approaches that hinge on cross-cultural exchange (e.g. Aikenhead & Jegede, 1999). Those who have invoked the notion of critical science agency similarly consider attention to norms, values and practices important, but are additionally concerned with historical power structures inside and outside of the classroom. They employ the notion of critical agency to conceptualize ways that students may challenge the traditional power structures of classrooms and schools, advance their own goals, particularly those that might be typically dismissed, and undermine historical stereotypes (Basu, 2008). On this basis, they emphasize a scientific literacy that is critical and transformative rather than functional: “While functional science and mathematical literacy emphasizes gaining the knowledge and skill for participating in society as it is now, critical science and mathematical literacy emphasizes developing the knowledge, practices, and discourses for transformative purposes,” (Tan, Calabrese Barton, Turner, & Gutierrez, 2012, p. 40).

In the last several years, the construct of critical science agency has been explored and developed in a handful of empirical studies, most of which were ethnographic in nature. A review of these studies will help to identify potential strengths and limitations of drawing upon critical science agency in thinking about science education for development.

Basu’s (2008) ethnographic study utilized in-depth interviews with high school students, their family members and their teachers, as well as schoolwork and participant observation, to examine goal setting as a component of critical science agency. From the

data, Basu identified a few goals articulated by youth that related to critical science agency, including wanting the content of their studies to reflect their own interests, wanting to be able to express personal opinions on controversial topics, and wanting to use the physics they learned to change the world.

Later, Basu and Calabrese Barton drew from the same research, using the experiences of two students, Neil and Donya, to elucidate three important components of their conception of critical science agency (Basu, Calabrese Barton, Clairmont, & Locke, 2009). First, from these accounts, Basu and Calabrese Barton identified critical science agency as “intimately related” to the development and leveraging of identity. For example, in the case of Neil, as he began to focus attention on robotics, both in the classroom and in outside activities, he left behind an identity of “playing dumb” in class, to take up the role of robotics expert and teacher. Donya leveraged her identity as someone interested in becoming a lawyer to design a science lesson for the class that involved debate. Second, Basu and Calabrese Barton described critical science agency as involving the strategic use of resources by students in pursuing their goals. Both Neil and Donya drew upon resources such as their teacher and their previous experiences within and outside of the classroom. Third, Calabrese Barton and Basu described the development of critical science agency as a process that is both iterative and generative. It was iterative in that each student reached their goals by reflecting on their own practice and modifying actions—in the building and programming of robots, as well as the planning of a class lesson. It was generative in that each student expanded his or her understanding and sphere of influence.

Calabrese Barton and Tan (2010) employed the construct to look at the relationship between informal science learning, identity, and agency in an extracurricular science program for middle school students. Their ethnographic account explored how students appropriated project activities in order to forge roles and a voice that challenged opportunities traditionally available to them in the classroom. While those offering the program had identified a particular plan of action, the students' interests led to new activities, specifically the creation of video documentaries investigating local knowledge and presenting the scientific understanding they had gained. According to Calabrese Barton and Tan, the youth demonstrated agency in their projects by authoring their own investigation and positioning themselves as community science experts.

In another study, Tan and Calabrese Barton (2012) drew upon a middle school unit on nutrition to explore the way that narrative could contribute to critical science literacy. Specifically, they saw the teacher's approach to teaching through having students articulate narratives from their own lives as creating 'hybrid spaces' for learning—in between spaces “where the multiple and oftentimes competing knowledges and discourses of scientific understanding, the complex food environment, and students' lives came together, informed each other, and were themselves challenged and reshaped” (Tan & Calabrese Barton, 2012, p. 101). In sharing stories as a part of their science learning, students were able to draw upon their own experience, contribute at a more equal level with the teacher, and appropriate the science content into relevant areas of their lives.

These four studies provide an overview of the ways in which the construct of critical science agency has been employed in science education literature, drawing from the most commonly cited articles on the subject. They give a purview of how the researchers

see agency manifest in the classroom: having a voice in shaping the approach to study in the classroom and in expressing opinions on controversial topics, considering the possibility of science careers in the future, and though receiving less attention, helping classmates in their learning, and sharing what they learn with others through documentaries and informal conversation. They also highlight some elements of the construct identified by researchers, such as: its connection to students setting goals for themselves, its close tie with identity development, the iterative and generative nature of critical science agency as a process, and the helpful role of third spaces where knowledge from home and school can interact.

As a construct, critical science agency has a number of characteristics that make it apt for thinking about potential contributions of science education to community development. For one, it considers science learning in the broader context of students' lives, their futures, and their place in society. As DeBoer's (2000) review of the history of science education attests, there are a number of purposes attributed to science education and ways it is envisioned to contribute to larger social processes. Often, though, these are not explicitly explored in the same discussions that address what the content of science learning should look like. And few have identified a role for science education in social change. Yet, questions about the contributions of science learning to larger social processes are central to thinking about the role of science education in community development. Articulations of critical science agency bring these questions to the fore. In so doing, the construct includes space for other elements of students' lives, recognizing other experiences, non-science knowledge, and meaning structures as pertinent to their learning of science.

Additionally, the specific description of agency offered by Calabrese Barton and Tan (2010)—that science agency implies the use of “the knowledge, practice, and context of science” towards ends of students’ development of their identities and efforts to alter the world—elucidates a connection between individual and collective change of particular use to thinking about science education for development. Furthermore, science education for development literature has identified science as of value to development efforts both in terms of specific knowledge content and in terms of scientific practice and approach. Such an orientation moves students from consumers of science in the learning process to some level of participation in the construction of knowledge. Of course, there are also limitations to the construct, which will be discussed further below.

Ways Students Demonstrate Agency

It is worth noting that the notion of critical science agency is derived from the work of Erin Turner, who introduced and explored the idea of critical mathematical agency. In their book *Empowering Science and Mathematics Education*, Tan and Calabrese Barton (2012) had Turner contribute with a chapter on “Critical Mathematical Agency in the Overcrowding at Francis Middle School Project.” In this chapter, Turner traced her notion of agency to the work of Holland, Lachicotte, Skinner and Cain (1998), whose theory is discussed in more depth in the next chapter. Since Holland et al. rooted agency in individuals’ participation and “figuring of self” in the daily activities of a given figured world, Turner suggested that in a classroom this might involve looking at the ways students position themselves to indicate competence or authority. Perhaps even more than in the field of science education, mathematics education researchers have advocated look-

ing at student agency as a means of “promoting more meaningful engagement in [the] discipline, productive mathematical identities, and enhanced student learning” (Turner, 2012, p. 54; see Allestaht-Snyder & Hart, 2001; Boaler & Greeno, 2000; Cobb, Gresalfi & Hodge, 2009). Turner has sought to build on the insights gleaned by these researchers by taking a stance that is more explicitly political, through a critical perspective, one that is oriented towards social transformation and justice. In the study mentioned in this chapter, Turner looked at a middle school mathematics project focused on overcrowding of the students’ school.

Following the efforts of students for the duration of the project, Turner sought to explore ways that students asserted critical mathematical agency, explaining, “given that agency is a rather elusive construct, and that as a field we are just beginning to understand what it might mean for students to enact critical agency in math classrooms, highlighting different ways that students demonstrate agency is important” (Turner, 2012, p. 56). Towards this end, she used vignettes from a middle school math project on overcrowding at the school to convey four ways that she and the teacher found students enacted critical mathematical agency during the project: (1) Students asserted intentions—desires, needs, interests, and goals grounded in what they bring to a situation and their sense of possibilities for the future—by defining math problems in the project that were personally meaningful, and advocating for particular ways to collect data and convey their findings. (2) Students demonstrated agency through acts of authoring, as they created their own perspectives on overcrowding and imagined more just ways that space could be allocated. For example, two students, despite the principal’s insistence that nothing could be done about load-bearing poles in the middle of the basketball court in the gym,

focused their research project on that topic. One of them suggested a video with an alternate storyline and in that way he “imagined (authored) a world in which he critiqued and transformed the school space, and then proceeded to create that world, to act it out, and to make it consequential” (p. 63). (3) Students enacted critical mathematical agency through acts of improvisation—responding to circumstances for which there was no set response—by inventing strategies for solving new problems and proposing scenarios that helped them explore aspects of overcrowding mathematically. For example, two students looked at the potential fire hazard created by narrow hallways by measuring the hallway in units of people who could fit in the hallway at the same time rather than use traditional units of area. (4) Students enacted critical mathematical agency through acts of critique, interrogating and critiquing their reality, and looking at how larger socioeconomic and political forces were reflected in their experiences. A few students, for example, discussed the possibility of whether it would be feasible for their school to switch places with another school in the same building with fewer students and more space, and concluded that there would be reluctance to switch because the other school catered to students with more money.

Such an exploration brings a useful level of concreteness to discussions of education-driven agency. It also highlights certain limitations to the way conceptions of critical science agency have been employed so far. These are discussed in the next subsection.

Problems of Individualism in Critical Science Agency

Concurrent to the aforementioned strengths of the construct of ‘critical science agency’ for science education for community development, there are certain ways in which its application in this area could be considered wanting. Though it has been described in terms that give eye to both individual and community change, the way its benefits have been captured in empirical studies has been largely in terms of a few effects on the individual visible from a classroom perspective: greater influence on the course of classroom learning activities and greater disposition towards the possibility of science-related careers. Little attention has been given to the influence of learning oriented to critical science agency on everyday decisions and behavior, or on collective well-being and progress.

By operationalizing critical agency largely in terms of student voice, as Calabrese Barton, Tan, and Lee have done, emphasis is placed on agency as the freedom to exert one’s individual preferences and shape things according to those. In the manifestations of agency described by Turner, for example, as “asserting intentions,” “authoring,” and “improvisation,” agency is when students make the projects their own. These conversations seem to imply that in conceptualizing agency, all freedom is good and all constraint is bad. This conflicts with the collective cohesion required of community.

Such an orientation arguably reflects individualistic tendencies that have been pervasive in Western culture for centuries. According to Abercrombie, Hill, and Turner (1986) the Enlightenment in Western Europe marked a philosophical and normative revolution in which the idea of individual rights displaced political obligations previously characterized by hierarchy and scriptural justification. Within this frame of thinking,

rights ascribed to individuals have primacy and all others, including social and political belonging, are secondary and derivative, ultimately intended to feed individual interest. In Calabrese Barton and Tan's (2010) definition of critical science agency, though it is interpreted here as implying both individual and collective benefits, one can see the primacy of the individual: "... agency with and in science implies that students use the knowledge, practice, and context of science *to develop their identities, to advance their positions in the world, and/or to alter the world toward what they envision as being more just*" (Calabrese Barton & Tan, 2010, p. 195, italics in original). In the learning process these authors envision, students should use science for their own benefit, both in terms of their identity development and their position in the world, and to shape the world according to *their own* vision. Here we see no responsibility to the collective or anything larger than oneself. The implications of such an individualistic perspective are hazardous to the work of community development, though prevalent in economic thinking. As Daly and Cobb (1989) note, current economic theory rests on individualistic concern for self-interest. It has no way to conceive of collective good, instead equating gains for society with the sum of gains to the individual. Policies that result from current economic theory weaken patterns of social relationships, thereby undermining the 'community' dimension of community development. From this perspective, this study seeks to utilize notions of science agency in a manner less constrained by individualistic patterns of thought.

The individualistic underpinnings of the construct of critical science agency have created at least two substantial limitations to its utility in thinking about the teaching and learning of science towards aims of community development. For one, they tend to over-emphasize freedom and downplay the potential for social structures themselves to be em-

powering by opening up opportunities for action. Examples of this sort of empowering constraint, which Monahan (2005) refers to as ‘structural flexibility,’ might include a wide open layout in classrooms that invites student mobility and collaboration, and technology policies that allow equipment to be purchase according to the needs of each local school.

Secondly, the outcomes of critical science agency are conceptualized purely in terms of the individual. Implications of science learning beyond individual students, implications for families, groups, institutions and communities, have not received attention. Focusing on the individual overlooks the interconnectedness of students to their communities and various collective configurations.

Given the individualistic assumptions that seem to be woven into discussions of critical science agency, one might argue that the construct is not one most appropriate to draw upon for an inquiry focused on community development. Yet, as mentioned above, the appeal of the construct is its concern for a role for science teaching in social transformation. The vision of agency taken up in this paper, then, centers on an enhanced capacity to act, including seeing options and taking action, of which one was not previously capable. Such agency requires both freedom to choose on the basis of personal preferences and structures that shape action.

Researching Science Agency

Research Questions

In light of the above discussion, this paper takes up and builds upon the notion of critical science agency in looking at an educational program with an approach to science education that both has dimensions of critical science agency as typically described, while also oriented toward development objectives of affecting individual behavior and collective social processes. Specifically, this chapter will explore the following questions with regard to the PSA program in Zambia:

- What does the study of science look like in PSA?
- How do students and tutors see themselves using the science they learn in ways they consider to benefit themselves and their communities?
- What sorts of agency do their experiences suggest?

The first two questions seek to root considerations of agency in an ethnographic account of science learning in the program and in participants' own accounts of their experiences. The third question looks to contribute to the manifestations of agency articulated by Turner (2012), potentially moving beyond agency at the level of personal expression.

Research Considerations

The first chapter provided an overview of the approach to data collection and analysis for this project. In this section, a few particular details of the research project are addressed as they relate to the findings. For example, it is worth considering the approach to examining agency undertaken here. While Turner's (2012) research drew pri-

marily from participant observation within the classroom, such an approach was not possible in this study, which is focused on how students were demonstrating agency in spaces outside of the classroom. To the extent possible, I participated in such spaces—meetings where students engaged members of the community about what they were learning, research activities where they sought to collect data about their microregion, and visits to activities of individual initiative, such as personal gardens. Yet, effective participant observation of such spaces was hindered on two accounts. First, usually English was not the primary language of such spaces. Second, in certain types of spaces (or perhaps all) there were effects of my presence as a visually noticeable outsider. In more than one instance, comments made by people participating in such spaces suggested that they equated my presence with certain development projects that extract local knowledge for personal gain or with funding opportunities for Inshindo.

For these reasons, while those experiences are also taken into consideration, the exploration of agency in this chapter draws primarily from participants' own accounts of their efforts and experiences. The value of such an approach is that it provides access to a variety of dimensions of participants' use of science, which one may not be able to see in making appointments to be in particular spaces. It also privileges the students' and tutors' own perceptions of the value of their science learning and ways that they are using it. Any connections mentioned are ones they themselves feel exist. The potential limitations of such an approach are that it is difficult to triangulate the descriptions of participants with other measurements of their behavior. Nonetheless, given the initial, exploratory nature of this inquiry, the comments of students and tutors are important in identifying new potential dimensions of agency. Taking only manifestations of agency reoccur-

ring among a number of participants' comments, it seems reasonable to consider them valid dimensions of experience in the program.

Learning Science in PSA

As pointed out in the introduction, the Preparation for Social Action program is not focused exclusively on the teaching and learning of science, though science concepts form a sizeable component of the content. In looking here at the study of science in PSA, then, an effort is made not to artificially separate the science content from the rest of the program, while also extending particular focus to it and its contribution to community development.

The study of science in the PSA groups in Kabwe incorporated a range of topics and activities. The summary excerpts of field notes below, taken from visits to a single PSA group, give something of a sense of the dynamics of science study in the program.

November 2011. Five students and their tutor sat inside a freshly painted baby-blue classroom of the community youth center. The tutor reminded the group that Elijah – youngest of the group, in his early twenties, short and jovial – had been asked to prepare what the group would do during the upcoming community meeting. Elijah declared that he had prepared some, but had not been home enough those days to finish the preparation. Since they have just finished studying “Ecosystems,” he remarked, they will talk about the importance of protecting ecosystems. They can tell community members about the visits they made to two nearby ponds. One had many fish and the other had none, he reminded. ‘We can tell them our data, that when we measured the pH, we found it was 6.5 for the fish pond and very high, 8, for the non-fish one. And the pond with no fish also had a temperature between 31 and 34 degrees, too high. Fish should live between 20 and 28 degrees centigrade. This one shows that ecosystems need to be protected otherwise the animals that live in them can die.’

Another student suggested they talk about the importance of trees. In a different activity they had visited a forest. ‘Trees will help us to have the rains.’ Another added, ‘planting trees and grass reduces the soil erosion by the wind. This was especially important here in Kabwe, because

of the lead pollution in the soil.’ When the wind blows up the dry dusty dirt, people inhale toxic lead.

A third added, ‘Perhaps we should talk about gardens. We have to change the perception that the forest is an ecosystem we have to protect, but not our yard. We can share the idea of using manure instead of fertilizer and chili for pest control [instead of chemical insecticides.]’

The tutor asked, ‘How are you going to work with the community on these issues?’

December 2011. Three students and the tutor sat at desks in the same baby-blue classroom, with a textbook unit called “Diversified High-Efficiency Plots” out in front of them. They took turns reading from a lesson set up as a dialogue between four characters. The characters were discussing various types of irrigation. Periodically, the tutor stopped the group and asked them to comment on what they have understood. They paused for a while at a diagram showing seven different types of irrigations systems. ‘How does flood irrigation work?’ the tutor asked. ‘How about drip irrigation?’ ‘Which ones are used most in our microregion?’ The students took turns answering. ‘I think there are three.’ ‘I think there are just two, flood irrigation and furrow irrigation.’ ‘Which one is the most economical in terms of water use?’ ‘Which is the cheapest?’

Later in the lesson, they studied the water cycle. The language of these paragraphs was more difficult and the group took longer pauses after each paragraph. A few of the tutor’s questions went unanswered and so he answered them himself paraphrasing and summarizing the ideas in the book. The group then discussed ways that certain practices—for example, planting trees, maintaining biodiversity, using precise irrigation methods, and protecting the soil from erosion—could protect the amount of fresh water in the region. Towards the end of the lesson, the text presented a few proverbs about water and asks students to write a few lines or a short poem about water. The study ended early so that the tutor could secure the land where the group intended to grow its own DHE plot.

January 2012. Two students and the tutor met in front of the youth center and then headed north through a residential area and toward the fields on the outskirts of town. They had recently studied a lesson about technological choice in the context of the sequence of tasks carried out in an agricultural production system. A few minutes after they set out, they were sitting in the shade of a home with older woman. The woman’s wrinkles and slightly hunched posture suggested she was in her sixties, or perhaps seventies. Like most other women on the street, around her waist was wrapped an African print cloth, *chitenge*, which extended to her feet, and she carried a tiny hoe, only a foot and a half long. One of the students spoke the local language of the woman—both were from a distant province—and he served as the primary interviewer, asking questions and writing notes on the back of a textbook. ‘Tell us about the work you do in farming,’ he asked in the local language, ‘What do you do first? ... Then

what next? ... How do you prepare the land? ... When? ... Why is it done that way?’

April 2012. The tutor and three students stood around a table full of materials: a glass jar of some translucent brown liquid, two plastic containers of a clear liquid and a yellow liquid, a Bunsen burner, several other containers of various sizes with yellow, gray, and blue powders in them, a whole box of test tubes, two wooden test tube holders, a test tube clip, matches, a mortar. They opened the unit “Growth of a Plant” to Lesson 9; it had been a while since they studied this lesson, but since they now had access to the necessary materials, they were able to complete the practical activity. At the tutor’s instruction, the group reread a couple paragraphs from the lesson:

“Acids make up another set of substances. You have probably heard of some acids, such as sulfuric acid and hydrochloric acid. The latter is found in our stomachs and helps digest food. Another substance in this category is citric acid, which can be found in the juice of citrus fruits.

“Acids and metals interact with each other, and one way of identifying a specific metal is by looking at what happens when you combine it with an acid. Your tutor will give you a sample of six metals: copper, aluminum, lead, iron, zinc, and magnesium. Observe, examine, and describe each one.

“Take 18 test tubes, separate them into groups of three, and place each group next to one of the metal samples. In each group of three test tubes, fill one halfway with sulfuric acid, one with nitric acid, and the last with hydrochloric acid. Then place a piece of metal into each tube and observe what happens...”

The students took turns using large plastic tweezers to drop small pieces of metal in test tubes half filled with liquid. Some produced a sizzling sound and released gas; others caused the liquid to change color and released an odor that students commented on. In other cases, only a few bubbles were produced, and at the suggestion of the tutor, two students used the Bunsen burner and a test tube clip to heat the test tube. Heavy gases were produced and the liquid changed color in each instance. The tutor asked students to take turns explaining what happened in each instance, and all jotted down notes in a chart provided in their textbooks.

This series of snapshots conveys a few reoccurring characteristics of what the learning of science looked like among PSA groups in Kabwe. First, it highlights the range of science-related topics that form part of the study. As the introduction chapter

noted, a few of the text units are directed at the development of the capabilities of scientists and the content helps students become increasingly acquainted with the atomic theory of matter, drawing concepts and information from the fields of physics, chemistry and biology. The activity to observe the chemical reactions between metals and acids was one part of that line of study. In other lessons of that same unit, students were introduced to the concepts of cells and tissues and examined a thin slice of bean root under a microscope. In many other text units, students study scientific concepts as they relate to processes of community life—agricultural processes, processes to maintain and protect the health of the environment, and processes to maintain the health of members of the community.

Second, the glimpse of the activities of this PSA group draws attention to the connection that is explicitly made between the ideas of the textbooks and local conditions. Specifically, most of the texts draw upon the concept of a “microregion” as a relatively small geographic region where conditions are generally similar and the activities of people are closely related. Students are often asked by the texts to research conditions or common practices in their microregion and tutors similarly ask students to compare what they are reading in the books with what they know of their own microregion, as the tutor did above.

Third, and relatedly, the above excerpts reflect the relationship of learning to practice in the study of the program. Textbooks contain a number of hands-on activities to illustrate a concept, experiments, research exercises, and other activities beyond the scope of text study and conversation. Those at Inshindo refer to these broadly as the “practices” of the book. Students describe these activities as one of the characteristics of

their study in PSA that they appreciate most, particularly as it relates to science. One student (Pushi 5F) explained:

This book which we just finished studying, 'Growth of a Plant', the things which are in that book are the things which are in school. Compounds, mixtures, chemical reactions. They are the same ideas, but different explanations, whereby at school when you go and learn that side, you can even understand better after learning here. The difference is that here we are even making experiments. At school most of the times we don't do experiments.

And a graduate (Lubambe 4F) echoed:

The way we used to learn in school, you just learned without doing the practices. Only once, in grade 12, during the final exam we did the practice of testing for starch. But with PSA we learn and do the practices right there to help us understand more. At school we just used to write down the procedure for what to do instead of practicing ourselves. For example just draw and label a microscope. We didn't get to use the microscope... If you learn without practicing it is very difficult for you to understand or for you to remember. I liked the practice of seeing the inside part of an onion and a stem. At school, when we used to draw those cells, and label them, without seeing the way it looked like, so I was at an advantage compared to my friends [because] I had used the microscope in real life in PSA.

The practices of the program are one thing that set it apart for students, especially in the science content. In their study of science in school, students did not have an opportunity to use many of the instruments they discussed or to see first hand experiments that were described. For several, their study in PSA was their first time even using a thermometer.

At a deeper level, this seemed to imply for students particular meaning for their study. Repeatedly they remarked that they saw themselves studying to put what they were learning in practice. For example, one graduate (Kolwe 1M) commented:

In PSA, the benefits are, I have gained some knowledge in PSA, the knowledge that I didn't get from any other, maybe I can say, which I didn't get from my secondary school, not even from my primary school. And some which I got from there but I wouldn't think of them being helpful to me, yeah. Because there [in school] we could just learn, so that you

can understand the concept for you to write the exam. But with PSA I think we learn so that we can even apply it in our daily lives. So that's where, that's the benefit I have gotten from PSA. PSA has taught me about certain concepts, I have understood them, and it's now for me to apply them in my daily life... So what I've learned in PSA, I have to translate it into the actions. Yeah. So that's where the difference is.

Many, like this student, contrasted such a vision of learning with their experience in school. Several mentioned that they see themselves applying what they learn for their own improvement and the improvement of their community. These ideas are explored in greater depth in the fourth chapter, but are briefly introduced here as they frame thinking about the study of science in PSA and ways that students were using what they learned.

At the same time, the excerpts above highlight two of the most pressing challenges faced by many of the PSA groups in Kabwe and ways that the implementation of the program currently falls short of the ideal. The first relates to attendance. While the groups started out larger, by the time this group was nearing completion of the program, there were only three or four students attending regularly. The problem of attendance was prevalent across groups and often raised in meetings of tutors and coordinators. The second challenge is related to carrying out the practices. As was the case for the experiments in "Growth of a Plant" mentioned above, it was not uncommon for several PSA groups to move ahead with the study of the book, while they struggled to get things in order to carry out the prescribed practices. They then carried out the practice activities much later, and disconnected from the context of the study.

These five points provide a view of some of the major characteristics of the study of science in the PSA program, thereby setting the stage for a look at how students were using their science learning and the types of agency implied by their experiences.

Ways of Using Science Learning

The second question of this chapter relates to how students were using the science they were learning in the program. Given arguments that traditional science education is disconnected from the everyday lives of students (Aikenhead, 2006), there is particular interest around the question of what are points of connection between science learning and students' lives outside of the classroom.

In the case of the PSA program, the texts played a key role in tying together classroom study and life outside of school. They called upon students to draw upon previous knowledge and experiences. Certain lessons tasked students with asking questions of members of their community, carrying out research, growing food, and sharing ideas they were learning through informal conversations or community gatherings, among others.

Participants' accounts of how they were using the science they were learning, then, included both activities they carried out as a part of their studies, and ways that they were putting it to use beyond those activities, of their own accord. Often lines were blurred, as students kept in contact with individuals they first reached out to as a part of their studies or kept up actions that began as an assignment.

The activities participants mentioned were primarily related to agriculture and environmental protection, though they sometimes dealt with health and sometimes related to scientific practice and content in general. The chart below provides an overview of the ways in which students and tutors mentioned using their science learning.

Table 3. Ways Students and Tutors are Using their Science Learning

	Agriculture	Environmental protection	Health	Other dimensions of science
Uses of science learning that were part of formal study	<ul style="list-style-type: none"> • Growing crops and vegetables with classmates • Speaking to local farmers about their practices • Researching the prevalence of backyard gardens in the community • Working with neighbors to help them start gardens 	<ul style="list-style-type: none"> • Speaking to others about air pollution • Researching waste management practices of small manufacturers and large industries • Measuring solid waste pollution • Speaking to others about solid waste pollution • Measuring health indicators of nearby ecosystems • Planting trees 	<ul style="list-style-type: none"> • Researching prevalence of skin diseases in children under 5 and ways mothers treat them • Holding a community gathering to discuss intestinal parasites • Raising awareness about the causes of malaria through community gatherings or informal conversations 	
Emergent uses of science learning	<ul style="list-style-type: none"> • Starting a garden or agricultural plot at home • Applying learned techniques to preexisting home gardens/plots • Sharing certain techniques or concepts with family, friends or neighbors • Helping others to improve their gardens/plots • Experimenting and trying new things based on concepts learned 	<ul style="list-style-type: none"> • Using less plastic bags; reusing or repurposing plastic bags • Separating biodegradable and non-biodegradable waste at home • Composting • Starting environmental clubs in schools • Trying to start a waste management service • Collaborating with the local government around waste management 	<ul style="list-style-type: none"> • Holding classes for mothers at the local clinic 	<ul style="list-style-type: none"> • Understanding better the science learned in high school • Retaking the science end-of-school exam • Feeling more confident in science • Approaching things in a scientific manner • Asking questions and trying to figure out the reasons behind things • Using metaphors of scientific explanations of phenomena to conceptualize social phenomena

These uses of science learning had benefits for both the students and others with whom they interact. The science learning fostered the development of the individual participant, as their understanding of science advanced, as they felt more confident with science and perhaps took school science exams, and as they took approaches they considered more scientific in various spheres of endeavor. Students and their families benefited, as they applied agricultural techniques to home gardens or plots, potentially growing more food for the family or generating enough to yield a small income. At the same time, the community benefitted as students share what they are learning with others, adopted and encouraged practices that are more beneficial to the local environment, and generated greater information about local conditions.

Instances of Critical Science Agency for Community Development

The ways students identified themselves as using their science learning shed light on how science education can contribute to community development. The concern of this chapter is to identify manifestations of critical science agency that are particularly pertinent to thinking about science education for community development. As identified in the introduction, the manifestations of agency identified by Turner (2012)—agency as asserting intentions, agency as authoring, agency as improvisation, and agency as critique—contribute to aims of having students' voices heard in the classroom and having them consider science-related careers. If aims of science learning are directed at improvement of individual life circumstances and community circumstances, as have been discussed, different manifestations of agency may need to be given more weight. Derived from the comments of PSA participants about how they saw themselves using what

they learned, three manifestations of agency are explored below. Just as the comments of a few dozen people participating in the early years of one program's implementation will not provide a comprehensive list of ways science learning can contribute to community development, these three conceptions of agency are not exhaustive, nor do they seek to exclude or belittle the instances identified by Turner. Each of the three conceptions of agency draw upon two dimensions of agency identified in the literature:

- Agency as the expanded capacity to act
- Agency as using the knowledge, practice, and context of science to help themselves and influence the world

Such conceptualizations of agency favor the potential to act within the context of one's life over having a voice in the classroom. As the next chapter will explore in greater depth, these two are not unrelated and active participation in the classroom is closely related to the types of agency discussed below. Yet, for this inquiry into agency, undertaken with an eye toward social change through participation in community development, agency as having a voice is insufficient.

Agency as Applying Learning to Practice

Many researchers, such as Aikenhead (2006), argue that traditional science education is characterized by a "pipeline" approach in which the underlying purpose of studying science is to adequately prepare for the next level of science courses, acquiring necessary skills and information, until ultimately the most capable students take up science and engineering careers. The sort of science taught in these courses has little relevance to students' everyday lives and it becomes difficult to identify ways in which the content

students learn in school has an impact on their lives outside of the classroom, beyond influencing their career tracks.

The potential of science education to contribute to community development, however, relies upon the possibility that the things students learn in school may affect actions outside of the classroom. In that light, applying learning to practice is one critical manifestation of agency, for it is the ability to first see the implications of learned information, concepts, abilities, and approaches for one's actions and then employ them in one's own life that constitutes a cornerstone element of science education's potential contribution to community development.

The ways in which science learning can be translated to action are many. In order to constitute critical science agency, as conceptualized in this paper, such instances must reflect enhanced capacity to act through the study of science content, and that developed capacity for action should allow the individual to better help themselves and influence the world in a manner that potentially contributes to community development.

Below two case examples are presented that represent two different points along what might be considered a spectrum of critical science agency as applying learning to practice. As students with diverse experiences, opportunities and inclinations study a particular science content, the depth with which they engage with it and apply it to their lives will necessarily vary.

Hillary. Hillary was a soft-spoken woman in her mid-twenties who had graduated from the program a year before the interview. A young mother who spent her time caring for her infant son, she described herself as 'doing nothing' when she heard about the program from her niece. She followed her niece to one of the meetings and decided to join,

though by then the group was already studying their third book. When two months later the woman who cared for her son during class got sick, Hillary found a way to continue by switching to a group in another community and leaving the boy with his grandmother.

In recounting her experience in PSA, Hillary centered conversation on three units, her three favorites: ‘Planting Crops,’ which is focused on agriculture, ‘Environmental Issues,’ focused on environmental protection, and ‘Nurturing Young Minds,’ focused on preschool education. When asked about other textbooks, or even certain parts of ‘Environmental Issues,’ she mentioned that at one point she missed many classes due to her son’s illness at that time, and couldn’t remember the days she did attend. Pressed further, she clarified, “I was mostly interested in the garden part.”

After the study of ‘Planting Crops,’ Hillary started a garden on the land near her in-law’s home, where she lived, inspired by what she was learning in PSA and the demonstration garden her group had created together. She described:

I got the idea [for the garden] from what I learned [in PSA]. Then for the seeds, it’s the people who I’m living with [my in-laws] who helped me to buy the seeds, because they were also interested in learning from what I was doing.

In the garden, Hillary planted tomatoes and two very common types of leafy green vegetables, referred to as ‘rape’ and ‘Chinese cabbage’. She planted enough to sell some of the yield to neighbors, earning a small sum of supplemental income. In tending to her vegetable garden, Hillary applied things she learned in two of her favorite textbooks:

I started with [preparing] compost manure. I went to the pit, where we used to throw garbages, there I separated. Those nonbiodegradable waste, I put them aside, and the biodegradable waste, I got them and put them in just like a small yard. I mixed the manure in the soil there and started watering. After watering, while the nursery was on there, I started transplanting them, after making beds, nice beds. Then after that I continued watering, then I saw some insects in my rape [leafy green vegetable], it was

rape, they were eating my rape. Then from there, I just got tobacco and mixed it with water. After two days I sprayed it in my vegetables and the insects were all gone.

The technique of spraying plants with tobacco soaked in water to ward off insects was one Hillary had first been exposed to as her group studied “Planting Crops.” The idea of separating biodegradable from nonbiodegradable waste was one introduced in “Environmental Issues.” Other techniques she mentioned learning about in PSA and then using were planting certain plants 5 cm apart from one another, using different types of manure instead of chemical fertilizers, planting maize, squash, and beans together on the same land, and preparing the land by digging furrows and burying leaves in them prior to planting.

About these techniques, Hillary was able to provide a few simple explanations about why that particular technique was preferable, but could not go into much more depth beyond that. For example:

H: When we were learning about how to grow a garden [as a child], [with] my father we were using chemicals, but this is not a good way of making a garden, better you use this manure and tobacco.

EL: Why is it better?

H: Tobacco is not harmful. Even if you have sprayed it today, you can still use the vegetables today. Rather than chemicals, if you spray chemicals to your vegetables today, and you use vegetables the same day you have sprayed the chemicals, you can become sick or just to die.

And:

I separate the garbage because the non-biodegradable ones, they are like plastic and others, they do not break down into the ground. But the biodegradable ones, like corn stalks or leaves or papaya skin, they are biodegradable and when they break down they give nutrients to the soil.

Such explanations reflected a basic understanding of certain scientific concepts, or at least provided reason enough for her to choose to employ certain techniques over others.

In the first explanation, Hillary referenced a simple comparison of toxicity levels after spraying for pest control, as determined by how quickly the vegetables can be used after spraying them. Such an explanation relates closely to her personal experience. The second explanation relies upon a categorization of waste introduced in “Environmental Issues”—biodegradable and non-biodegradable waste—and a simple scientific explanation of why it matters to separate the trash. The terms ‘biodegradable’ and ‘non-biodegradable’ came up multiple times in Hillary’s interview, and seemed to constitute an important conceptual resource for her.

Not all the explanations Hillary provided were rooted in sound scientific understanding. In one case, Hillary described a practice that she began using as a result of her studies, leaving a certain amount of space between the seeds planted, but provided an incorrect explanation:

You leave space even for the sun... There must be space for the sun to penetrate, because if they [the plants] are so squeezed, they won’t develop well, because the ground also needs sunlight. If they just cover it, the ground isn’t going to receive sunlight.

While spacing of plants is important in order to allow each plant to have enough access to sunlight, water, and nutrients in the soil, it is not necessarily the case that it is important for the soil itself to have sunlight access. In this case, it seems likely that Hillary had misremembered the reason while recalling the technique.

Hillary, then, provides an example of a student with a rather narrow interest who engaged the content most strongly around a particular topic. Specific gardening techniques introduced in class were important to her and continued to be used by her long after graduating. While her recollection and understanding of the scientific concepts underpinning particular choices of technique were not strong at the time of the interview,

she continued to find value in what she learned and apply the ideas she found most helpful to her efforts to grow a small backyard garden. Her experience suggests a rather straightforward and simple example of science agency as applying learning to practice. Although growing some of her food was not entirely foreign to her, because most families in the region at least grow a small plot of maize for personal use, Hillary was encouraged by her study of agricultural topics to begin to grow vegetables as well, thereby translating some of what she learned in class into changes in her ongoing actions and behavior. These actions were beneficial to herself and her family, providing a supplemental income for the family, while also beneficial to the community in providing access to vegetables without chemical residue on them grown in a manner that was more environmentally sustainable.

Alvin. Alvin first joined the PSA program as a tutor. His first encounters with the textbooks, then, were during two-week periods of intensive study, during which the tutors studied the units as students in preparation for tutoring them in the months that followed. Like Hillary, Alvin appreciated the study of agricultural topics and was inspired to apply what he learned to his garden and small agricultural plot:

[Before] I was one person who didn't like things to do with farming. We used to wrestle with my parents when it comes to go to the farm. But now I got that interest in farming, after the studying the books, it was so much interest in doing so I was eager to know and learn more about these things about agriculture and stuff.

He planted a backyard garden near his house and worked with his uncle to plant soya beans, Chinese cabbage, maize, and groundnuts on the uncle's farm. After his uncle had experienced difficulty in growing maize on the plot, Alvin explained to him what he was learning in PSA about soil health and the two decided to try soya beans instead. After a

successful harvest, they then planted the cabbage, maize, and groundnuts, with a live fence of cassava, as Alvin had learned about in his studies.

As Alvin recounted the experience of studying and helping his uncle, he spoke excitedly about ideas he found valuable in his studies. For example:

In Planting Crops, I think the part when we started doing the soil testing, yeah that one was very also interesting to me because I did not know about that the soil can have these ranging through all these different stuff, they can be alkaline, they can be acidic, then it came to me to say oh, I can do something, if I see the maize is not doing fine, maybe there's another crop that I can plant from there that can support that one, instead of saying you know it's a waste, there's nothing you can plant, maize does not grow. So you take it that any crop you plant there cannot grow. And you have nothing to do about it. But when I came to learn these things, I came to understand to say, okay, so the soil I can help it, if it's alkaline, if it's acidic, there's something I can do to improve the quality of soil. Yeah. And maybe just changing the type of crop that can be planted in there. That also can help in improving the quality of the soil.

In this case, and a couple other examples he mentioned, the concepts introduced in the textbooks encouraged Alvin to recognize new possibilities for action, to think when faced with particular challenges that "I can do something." While previously, he and his uncle had believed a particular plot of land was useless, the notion of acidic and alkaline soils led him to try different ways of using the soil, planting different crops and employing chicken manure and leaves to enrich the clay soil in his garden. Here agency was rooted in understanding.

In addition to the implications on his actions of advances in understanding, Alvin identified changes to his approach to various activities as a result of his study of scientific content. He explained:

In my case, I think it is so much important to learn the science part we are learning in PSA when it comes for you, for your own life, how you apply certain things. Do you just receive something, like a theory, without investigating about it, without learning more about it? ...I have to ask a lot

of questions. So for me, for many things, I have like also developed such a mind of a scientist, to [think about] how these things are working this way. What other things maybe can I find out? Which can help into maybe working well? Or how did people came up with that conclusion? What methods did they use? How did they arrive at that conclusion for me to believe in it?

In this and other places he described himself as coming to think like a scientist as a result of his studies in PSA, and characterized this development as asking many questions.

From the above comment he continued, adding that such an approach has caused him to persevere in looking for answers:

So, in my case, I think the learning of science has brought to me that there's nothing like failure. To me, that's one thing it has brought to me... Then to me, [it means] if I'm making something and it hasn't worked out, then I have to find another way of doing it. Even my life, I use that scientific approach.

Such an approach was evident in his description of his agricultural experiences, but when asked for an example, he shared from another area of activity:

I remember I was helping to do wiring of a certain house and the electricity was not also on. So I went out, we tried this and this, things couldn't work out. There were all these sparks around the house. So I tried this and then I told them to say, I have to go home. I will come back tomorrow—to fix it, not to find the problem. So when I slept, I started asking those questions. I had a diagram of the whole house, and where things are not working, where I tried this it can't work out, and that to fix it in the night. 'Ah, I think if I tried this and that, I think it will work out.' So when I went there I fixed it in twenty minutes. And the people were like 'ah, so you were serious that you were going to fix it at home, how did you do it?' I said, 'no it's something, not magic, but it's something I went to analyze and ask myself questions why it doesn't work.' So to me in this area, in the technical area, it's really helping me so much. Because if something is failing, I ask these questions and want to find out.

Alvin, then, applied his science learning to practice in a manner beyond the application of particular techniques. While he did not learn about electricity or electrical engineering in his study of science in PSA, he found that attitudes and approaches he had developed in

that study changed his action in that realm as well. He found himself asking more questions, why did this happen, what is another way of doing this, and such questions influenced his actions. In the example he provided, it caused him to persevere in resolving an electrical problem in the wiring of a house. In the case of his uncle's infertile field, it led them to try planting a different crop to see if it might produce better yields. In each case it was the combination of scientific knowledge—about electricity and soil fertility—and scientific attitudes and qualities that contributed to practice, according to Alvin's description.

The spectrum. The cases of Hillary and Alvin shed light on what can be considered a spectrum of science agency through applying learning to practice. In theirs and many other cases, participants put the science they had learned in school to use in their personal actions and behaviors. In each case, their action was different before they began their study. They started gardens or changed particular agricultural practices; they sorted trash in order to compost or reused plastics; they approached tasks in a manner that asked more questions or incorporated experimentation.

At the simpler end of the spectrum, students such as Hillary gained from their science learning an exposure to particular techniques, an opportunity to develop certain skills, and an interaction with scientific explanations that impacted their practice in some straightforward way. Twenty participants in this study recounted changes to their actions in a manner that reflected this rather simple manifestation of agency. While a few described changes to practices around waste management, a majority mentioned putting into practice ideas related to gardening and agriculture. In each case, capacity to act was extended through study as participants expanded their repertoire of practice on the basis

of what they learned. Having each participated in gardening and agricultural activities during the course of their studies, participants could easily draw upon such experiences in family plots.

At another level, nine students and tutors recounted changes to their actions beyond the level of technique. Rather than simply applying a particular way of doing things, these individuals mentioned drawing from concepts they had learned in order to make decisions about a course of action specific to particular circumstances. This was seen, for example, in the decision of Alvin and his uncle to try planting soya beans because of what Alvin learned about soil chemistry. Other students mentioned taking into consideration several factors in determining which types of manure and fertilizer to use, and coming up with their own ways of reusing plastic or reducing its use.

Finally, five participants described changes to their efforts at the level of approach, characterizing their efforts as ‘more scientific,’ ‘asking more questions and trying to find out answers,’ and striving to figure out the reason behind things. Alvin described taking such an approach both in agriculture and in applying his electrical engineering skills. The other four similarly characterized this as a broad change in their approach to many aspects of life, then provided examples primarily in the area of agriculture. One person described that he had studied agriculture in school, but back then he saw it as a series of steps to take. Now he understood the logic behind both the industrial agriculture that he learned about and what was described as conservation agriculture, and could conceptualize the merits of each, given particular circumstances.

This provides only a rough sketch of the range of science agency as students, of their own initiative, applied what they were learning to areas of activity outside of the

classroom. As the agency that students demonstrated varied, so too did the depth of scientific understanding from which they drew. Those who had changed in their use of particular techniques, often did connect such changes to scientific explanations, though these were often brief and occasionally incorrect. In more complex examples of agency, student accounts of their reasoning generally drew upon a more complex understanding of scientific concepts, about the make-up of the soil, for example. This is but one way student accounts suggested agency in using science towards ends of community development.

Agency as Drawing from and Contributing to Flows of Knowledge

A second way in which students demonstrated agency relevant to community development on the basis of their science learning was through their connections to flows of knowledge in the community. Through their studies, students both came to draw more from knowledge in the community and contribute to it. The two cases shared below provide an initial view of the spectrum of agency on this front.

Within education literature, a growing contingent of academics have stressed the importance of recognizing the funds of knowledge that students have access to in their homes and communities, from which they can draw upon in their studies (e.g. Moll, Amanti, Neff, & Gonzalez, 1992). Such awareness would seem to be particularly important to considerations of science education for community development. Of equal value is attention to the ways in which in school learning contributes back to the knowledge in families and communities. The accounts of participants in this study sug-

gest that connections to flows of knowledge in both directions were another important manifestation of science agency.

Mabel. Like Hillary, Mabel completed the PSA program a year prior to her interview. The two had been in the same group. Prior to her study in PSA, Mabel had been a part of a youth group formed by the health clinic and had a long time interest in both learning new things and contributing to her community. After graduation, she continued to be involved in service to the community with a focus on the moral and spiritual education of children and younger youth.

When asked to share about one of the science-related activities her group had carried out, Mabel chose to recount several activities from the unit “Environmental Issues” in which students spoke to members of the community to learn about how they were managing waste produced by manufacturing. These were some of the activities that had been most meaningful to her in her studies. For example, they visited a large manufacturing company:

M: We went to a factory that produced mealie meal [the local staple, made of ground maize] and we found the place, the industry was really polluted... You would find the air is polluted, where the water is going is also polluted. A lot of things... So after talking to them then they said, they really don't know how or where to take that kind of waste... So they thought maybe it will just rot on its own... So we asked them some questions, and those questions we were asking, we had some ideas on how they can do on that kind of waste that they were just heaping. Because that one was, if they were to sell it off to some farmers, farmers were going to use it for boosting the land, then also feeding the horses.

EL: Oh it's useful?

M: Yes, it's very much useful. But with them they never knew to say it was that useful. So after talking to them, asking them a lot of questions, then that's when they said, what you've said, that's maybe a good idea. We never thought maybe we can take these things to people that are in need of them. Maybe we can contact some farmers.

EL: How did you guys know that they could use that waste for those things?

M: We knew from many places. After studying ‘Environmental Issues,’ there are like those sections where we found those lessons of the non-biodegradable and biodegradables. So we saw even where like those things were put, the soil is really looking so nice.

EL: At the factory?

M: The soil was so nice, such that if it was a garden, it was going to produce a lot of healthy plants... Then there was even another person who said, we use these things at our farm for feeding, at their neighboring farm, they use them to feed some horses, and sometimes the cattle. So he also contributed to telling them.

In that visit, and other ones to local business owners including a tailor, a carpenter and the proprietor of a small store, the group got to know waste management practices in their community. They appreciated ways local manufacturers were already reusing and recycling their waste—for example, the tailor’s scraps were used to make doormats and the carpenter’s sawdust waste was used to fill holes and start fires. “These ones they were already using their waste instead of throwing it, it was so nice to find,” she commented. Sometimes on those visits, the students also shared things that they knew or had learned, as was the case for the mealie meal factory.

These sorts of exchanges with members of the community were components of a number of books, particularly those related to environmental protection, health, and agriculture. According to Mabel, this aspect of discussing ideas with members of the community was one she very much enjoyed. In addition to the activities of the group, she sometimes shared ideas informally with friends, family members, and neighbors. She described:

M: I’ve learned a lot of things that I never used to [know], and the things that I’ve learned, I’m not only keeping them to myself. I’m finding time, like sometimes when I interact with people, if I find a person has some difficulties and stuff, I relate them to the materials we used to study in PSA, to say... ‘can you try applying this and that? Then see the outcome’...

EL: Can you give an example where you did that?

M: Okay, when I did that was when the person was complaining of urea fertilizer. So after complaining of urea fertilizer, that's how I tried, I was like 'okay, I'm just only going to give you a try on what we studied. I've not used it. But I don't know how, if it works or it doesn't work. Can you just try, maybe just to get your urine, then you mix with some water, and then you try to put in your crops, the maize crops.'

EL: Urine? Is that what you said?

M: Yes, urine... (*laughs*)

EL: That's fertilizer?!

M: Yes.

EL: Oh! You learned that in PSA? ... In the books?

M: Yes.

EL: I don't remember that part.

M: That's urea. Then the person went, got a 2.5 container, just had a lid on that top of the container, urinated in it, then mixed with the water. Even checked it. After checking on it, waited for it like to settle and stuff, again that's how the person just went to try, just like a small path, then the most exciting thing, the maize was so nice than the other maize where he applied fertilizer. I was like, oh [goodness]. I think in the near future I will stop buying fertilizer, urea fertilizers, because I have the urea in me (*laughs*). I'm just keeping it. So it's better I just use like, I was just visiting this, the maize is looking so nice and everything after using those.

The idea of using urine as fertilizer is not one mentioned in the content of the PSA program, but it did come up in the discussions of Mabel's group, as participants drew from their own knowledge. Other instances Mabel mentioned of sharing ideas with others included telling friends and neighbors about organic manure, about the causes of malaria, and about the environmental damage caused by plastic, particularly overuse of plastic bags. In each case, she shared suggestions for practice and/or pieces of information with implications for practice. From her accounts, the scientific explanations in such exchanges were brief, but she found in them value for the community. She explained: "This kind of science here, it is not only using test tubes—okay, you could use test tubes—but also it is science for the community, science related to your daily life. So I learn and I share it with others."

Timothy. Timothy was a tutor in the northwest region of Mwinilunga who had a deep interest in agriculture since childhood. He explained:

Because my father was a farmer, so most of the times I used to be with him in the farm. Then I developed that interest of farming. Then when I was in high school, in grade 8, I started practicing gardening on my own.

Early on Timothy developed the habit of asking people for farming advice, out of a sincere desire to improve his practice. Since his parents moved back to Angola when he was young, he could not ask them questions and began to ask others he knew. Of his high school garden, he described:

T: It had a lot of challenges. Things wouldn't grow. Then I started consulting with people who were doing gardening... They told me about certain soils are not able to make certain crops grow. They were talking on certain soils have got the limit on the kind of crops that can grow in the soil. So then what they were telling me sometimes when these soils fails to grow crops, we add chemical fertilizer. That was their encouragement. We use fertilizer to fertilize the soil.

EL: So you started using fertilizer?

T: Yes I did.

EL: What did you find?

T: Crops could grow well, but the first experience I had was that, as I continued harvesting, at a certain point I could find that the taste of the vegetable changes. It tastes a little bit bitter. It was one thing I discovered. Another thing was that on the land I used fertilizer. Sometimes when I try putting different crops, sometimes they fail. Yes. Especially after a long period of using that fertilizer, you find crops may fail. So that they say, you add more again.

In asking others with more experience about farming, then, he was introduced to techniques that helped him address his early difficulties. In particular, he spoke to two teachers with an interest in farming. "From these two people," he explained, "I learned a number of things. And from there, I could see myself improving the way I was managing crops."

In joining PSA years later, Timothy had the opportunity to study agricultural science in more depth, learning about soil chemistry and soil biology, among other topics. He described that the greater understanding stemming from these explanations affected his agricultural practice.

Because a way I've liked this [study] is that I've learnt on how just the soil is. We have learned that it contains a number of microorganisms that play some important roles in the growth of a plant. So if I manage my crops poorly, I will choose that kind of technology that is to harm that environment around, that is maybe killing those organisms in there. [If I think] they don't affect crops in any way, they might be killed and tomorrow I will see I will have no good harvest.

This was one of several concepts Timothy found helpful in his study of science. Another he mentioned was how a plant grows:

With the "Growth of a Plant," some of the things we learned were specifically to look on how a plant grows... So I was very much interested when we learned on the root system and how it is made. We learned the structure of a root and what makes it able to absorb nutrients from the soil and then transport it to the rest of the plant for it to grow. That's one part where I learned that a plant feeds just like a human being, for it to grow. So one thing I learned was that the fertilizer we add to the soil, so like when we talk of fertilizer, when we add it to the soil, it dissolves in there and helps the plant get the nutrients it needs... like what happens in human beings. When I'm well fed, I expect to have a good growth. Then the cells divide and multiply well. Now I could understand better why the fertilizer was helping.

Timothy's study then enriched his understanding of practices he was already engaged in. Furthermore, it introduced him to new techniques, such as how to use organic fertilizers rather than chemical ones. In addition to these scientific concepts and new techniques, perhaps underlying them, were certain attitudes that Timothy also described as an important benefit of his studies, for example, an attitude of trying to work in harmony with the environment:

In PSA program I have learned a lot of things. And actually what we learn is to put this in action. One other thing I've found to be interesting is to work with the environment, that's living in harmony with the environment... So that has helped me also to learn on the importance of the nature, the natural environment. To just keep it safe, at my plot actually, I have managed to keep the natural trees around, of which most people in our communities can't [don't] do. When someone is going on building, the first task is that they clear the land out, clear all the trees. Yeah. That's one thing I have learned and put it in practice. My surrounding is maintained, I don't cut down the trees.

The scientific concepts, specific agricultural practices, and environmentally friendly attitudes that Timothy drew upon in his own practice were also things that he shared with others. He described a number of instances of sharing what he was learning, with neighbors:

Actually, this time around the crops I manage, people who visit my home ask questions on what chemical are you using. And when I say it's zero chemicals, they don't agree. [They don't believe me.] I tell them how they can do the same.

And with family members:

Like, two days ago my uncle visited. He lives in Solwezi. He visited and when he was home, he was like, 'oh, what are you doing here?' He could see things I am trying to do around the garden... I was able to explain to him the ways I am growing my plants.

Beyond mere explanations, he sometimes shared what he was learning by working alongside friends and family members, sharing ideas in action:

T: The first time I visited my sister's home, I could find, I look around their yard, no single crop is growing. So when I was trying to ask them, why do you not have a kitchen garden, so they gave a lot of challenges, to say, these soils around here, crops can't grow. I was like, 'why?' The reason they were giving was like, you know a long time ago we used a lot of fertilizer. So this time when we grow, nothing is growing. Another challenge they could give is no water, or the animals around, but all those challenges, I looked at them that we can solve them. So that somehow to improve soil fertility, by using some means of technology. That experience has improved it, through the learning of PSA materials, that we are able to improve our soils.

EL: So for your sister's garden what did you do?

T: ...I made a small fence to protect from animals. They were saying there are animals around here. So I made a fence and then I cultivated, then add some manure so the soil. I was using the leaves, dried leaves. I had to make furrows. So in those furrows I filled with dried leaves and some grass. Then buried everything. Then there was a period of time I could water that land, it took me like two months to recultivate. So I could see that the soil began changing. Then the time I started planting crops, the soil was already suitable for the crops. Then the result was we had a very good harvest.

For Timothy, then, the ideas he was exposed to and experiences he had in his studies became the basis of things he could share with others. While from the beginning of his interest in farming he found talking to other farmers important, his deeper study of the subject, drawing on both scientific explanations and firsthand experience, gave him exposure to more that he could share with others. In comparison with Mabel, he was sharing ideas from a practice he was engaged in, and he worked alongside others to translate ideas into action.

At the same time that he began to share more with others on the basis of what he was learning, Timothy also came to learn more from the community as a result of his studies. There were certain activities that called upon students to go and visit local farmers and ask about their experience and techniques. Timothy explained:

Our interests... was we go there and learn how they do their farming. So what we did was that, after the learning we went to our groups and settled. But it did not end there, we had some kind of regular visits to these people. We continued learning a few things from them and we were able to share with them the experience we have acquired from PSA program. And from among those farmers, one, I remember one, Mr. Elemi, there was Mr. Elemi, who became also very much interested that we continue collaborating. I'm sure that one we had worked with him for a long period of time.

In the practices, Timothy built relationships and engaged in exchanges multiple times over a long period of time. Through these activities, Timothy came to know better the kind of knowledge that already existed in the community. For example, he described:

When I learned [about polyculture] for the first time from PSA, I was wondering if, are there people in our microregion who are practicing the method. But then no, we went to visit some farmers nearby, and I came to learn that he [Mr. Chiyesu] is one of the farmers who is practicing that system of agriculture. I was surprised to find that it is already existing here.

He also built relationships upon which he continued to draw outside of the study:

We created that friendship with them [the farmers], where we could, after a period of time, we are able to go to these farmers, ask them how far they have gone with their farming, what are they planting in that particular season, or ask them if they have challenges. I still talk to them. Sometimes if a question comes in my farming, I will ask this one what he has done for this same issue. They can sometimes ask me too.

Some of the people Timothy met through his studies, then, became individuals with whom he continued to interact on the subject of agriculture.

The spectrum. The cases of Mabel and Timothy highlight a second manifestation of science agency for community development—drawing from and contributing to flows of knowledge in the community. Part of their study included activities where they visited members of their community to learn about their practices and often in the course of such conversations they shared ideas from what they were learning or from their own experiences. In that way, this participation in flows of knowledge was an organized part of their study. Yet, both Mabel and Timothy also mentioned talking about ideas related to the science content of their study informally with others as well. Their study equipped them with greater familiarity with particular concepts, information, and techniques that might be of interest to others; in other words, through their study they had more to share.

They also, as the next chapter will explore in more depth, had more experience sharing ideas. And finally, through the activities to reach out to the community, they sometimes made new contacts with whom they continued to interact.

As with science agency as applying learning to practice, participants' accounts of their use of science learning in flows of knowledge could be roughly grouped into three points along a continuum. In simple cases, like that of Mabel, participants described turning to members of their community for information and sharing things they were learning with others as one-time events. Such exchanges often occurred unplanned, when a family member or neighbor seemed to struggle with or express interest in a topic they had previously studied. Sometimes they shared with others advice that they hoped would change the behavior of those they knew, for example, suggesting that they use fewer plastic bags or use organic instead of chemical manure. The instances of drawing from others' knowledge that were described at this level were usually things that participants asked about as a part of the activities prescribed in the textbooks. Twenty-six participants described participation in flows of knowledge in this way.

At another level, thirteen participants described engaging in conversation with others regarding practices that they themselves were engaged in. Usually, these conversations were related to agriculture. In these cases, exchanges were often not one-time events. Though they were not frequent, they occurred periodically, as participants turned to neighbors and nearby farmers with whom they began to interact in the context of their studies or once they started gardens in their own homes. They asked fellow farmers how they dealt with particular problems, responded to questions of individuals passing by

their gardens, and took initiative to share with other ideas they were learning and putting into practice.

An additional six participants described a much more regular and in-depth conversation with others around agriculture that drew from their science learning in PSA. In a majority of these cases, participants described having a strong interest in agriculture before studying in PSA, and several of them, like Timothy, already had individuals with whom they spoke regularly about their practice. The scientific content they studied, then, became additional ideas that they could contribute to the conversation. And the activities that called upon them to go out and speak to other farmers as a part of the study exposed them to new contacts.

Agency as Generating Knowledge

A third manifestation of science agency for community development mentioned by participants related to generating knowledge about the local context. In addition to applying what they were learning, and drawing from and sharing ideas with others, participants were sometimes engaged in the generation of new knowledge. Within science education literature, this can be connected to proposals that science education involve student inquiry (e.g. Abd-El-Khalick et. al, 2004) and that in be connected to the local context (e.g. Semken & Butler Freeman, 2008).

Elijah and Kanini 3. At a community meeting, Elijah stood up in front of forty or so members of his community—fellow PSA students from three different groups, tutors, community leaders, and family members of PSA students—and recounted what his PSA group had been up to in the last few months. Behind him were three posters that read:

Table 4. Kanini 3 Posters at the Community Meeting

<u>A Healthy Pond Ecosystem</u>	<u>A Stressed Pond Ecosystem</u>	<u>Factors that Cause a Stressed Fish Pond</u>
<ul style="list-style-type: none"> • Water clean in color • Temperature between 20 - 28°C • pH of water is about 6.5 • Concentration of dissolved oxygen/ liter is 5.5 mg • Nitrogen is 1 mg • Phosphorous is 0.01 mg 	<ul style="list-style-type: none"> • Water was not clear, green in color • Temperature was about 31-34°C • pH was 8 	<ul style="list-style-type: none"> • Human activities <ul style="list-style-type: none"> • water pollution • over-fishing • industrial activities

Elijah described to those assembled the activities that his PSA group had recently undertaken in their study of “Ecosystems”:

In our study, we went to visit two nearby ponds. When we went there, we had some questions that we were following. We were looking at the ponds’ ecosystems, is it healthy, what kinds of things live there? So we were looking at the biotic and abiotic living things in the ponds. We made a list. We didn’t find a lot of abiotic, but a lot of biotic things. We also measured the water if it was acidic or alkaline. And we measured the temperature. We had all the instruments that were needed there with the thermometers and everything. What we found is that one pond was healthy but the other one wasn’t. The color was green and the temperature was too high. Even the pH was wrong. We have seen that this pond is polluted.

In this case, the students generated simple knowledge about two nearby ecosystems and thought about ways to help the stressed one. The knowledge they generated was not extensive, but included a list of biotic and abiotic components of the ecosystem, some qualitative descriptions of it, and a few simple measurements of the temperature and pH of the water. Such modest compilation of information about the ecosystem allowed the students to think about ways to contribute to its improvement. While, depending on their particular findings, the group could have identified a few small steps they might take to help the

ecosystem, in this particular case they instead decided to ask local leaders to use an abandoned swimming pool to create a small pond for raising fish to sell.

Alex and Insofu 1. Among the many activities carried out by the first PSA group in Insofu was a research project related to the health of young children in their community. The project was rooted in the unit ‘Health and Disease,’ a textbook that was still in pre-publication form and being studied by the group before the last few lessons were finished. Though the final lesson, which would likely direct students to carry out a more complex service project, was not yet written, the group ended up building upon a small research activity in Lesson 5.

Lesson 5 of the unit narrates the story of a group of mothers who regularly come together to talk about the health of their children. Through the story, students are exposed to a number of common skin ailments and means of both protecting children from the diseases and treating them once contracted. At the end of the lesson, a section titled ‘Practice’ asks students to initiate conversations with several mothers and ask about experiences of their children with skin ailments. Two charts are then provided in which students can organize their findings.

In Insofu 1, the students in the group divided into pairs to make visits to mothers, reaching a total of about 30 mothers. Alex, the tutor of the group, described it to me, roughly a year after the group had graduated:

A: We had to go and talk to the mothers. We went out to talk to the mothers, find about these scabies, skin rashes... First we did the research to find out what was on the ground, then we came back, analyzed, then we had to go back.

EL: What did the analysis look like?

A: After we all went out and talked to the mothers, we brought what we found together. Each one had written what the mothers said in the charts

[of the textbooks]. Then we shared and together made a big chart of all the information.

EL: What did you find?

A: Yeah, I don't remember all that well. It's been a while, but I think we found the mothers had seen a lot of these diseases, especially diaper rash.

The group, then, conducted simple research about common skin diseases faced by children under the age of five in their local community and ways that mothers addressed these diseases. The next lesson discussed intestinal parasites, and although the text itself encouraged the group to host a community meeting about parasites, the Insofu 1 group decided to return to the mothers they had previously talked to about skin diseases and learn about local experiences with intestinal ailments. They generated more information about this subject. Alex shared:

...The other common thing that we found was like these small children, the mothers were just asking them to go behind the house and help themselves [defecate], then later on, if the mother forgets, then that thing stays there. So that's the other habit, we tried to say no, maybe if a baby relieves himself or herself, they have to take it and clean up, throw it away. We also discovered some most of households didn't have toilets, so that posed a challenge. They didn't have toilets, maybe they are using the neighbors' toilets. So that means they have to keep very good friendship to make sure that, if they quarrel, then they will say, no don't use our toilets. So those are the, like that thing we've shared with the counselor and the RDC [local leaders], say 'no, we have discovered in our community that people don't have pit latrines'... They confess that we are very right, that's a challenge we have. So we also try to encourage the households if they can be constructing pit latrines. Yeah. And also the question of water came in. We also discovered that people just draw water from the well, they start using it [instead of boiling it first]. And also what we do, we found that in our research, that maybe in the same yard there will be a toilet and a well. The distance was maybe 10 meters apart, so those are the issues we are trying to find out. Of course we had to ask the clinic staff, they said no that's not a safe distance.

On the basis of what they found in the research they conducted about local experiences, the Insofu 1 PSA group took a number of different actions. As described in this passage, they shared what they found with local leaders. Also, prior to this step, they

checked what they were seeing against knowledge of experts. They asked workers at the clinic if 10 meters distance between a latrine and a well providing drinking water was enough. In another example, they spoke to a doctor about how to prevent diaper rash:

A: When we were talking in our group about how the mothers treated diseases, I remember we had an argument over, like diaper rash. Because most of them they buy this powder, then they sprinkle to the napkins [diapers], then some they say you have to use vaseline so that it creates that shield. So there was that, now powder or this, so the students had to go to the resources to find, even from those mothers, how to go about it.

EL: So what did they find out?

A: [Dr. Meleki] helped us to answer, she said it's better they use vaseline, because some of the powders are not good for babies. Yeah. And then the other interesting thing we learned was, like when diaper rash, it was like you know, because traditionally in Zambia, whenever they put a napkin, then they cover with another cloth, then that thing made of plastics will cover the babies, so that if the baby pees or urinates, it doesn't drip to the mother... So there is that sensitization whereby we shared they have to be changing napkins regularly, because some of them they just put it and leave it the whole day. So that creates a lot of heat there.

The doctor helped the students to navigate a question that they came across in their research. In addition to sharing with local leaders and gathering relevant information from those with particular expertise, the group returned to the mothers themselves to share what they found.

We had to share what we had found out. We said [to the mothers], 'when we came here, what you said was A, B, C, D. The total of all the mothers was X, Y, Z. This disease was the most common. Now from our learning and the experiences, I think if we have to prevent this disease, we have to do A, B, C, D.'

The idea of going back to the mothers and sharing their findings was not one mentioned explicitly in the text, but emerged from the initiative of the tutor and the group. It perhaps reflected an ongoing rhythm of the group, who by this time had carried out several research and awareness-raising projects. It likely also reflected the personal interests or excitement on the part of those particular students:

I think that's the text which excited people the most... "Health and Disease," I think people they really loved it... Because we realized that no, babies succumb easily to these diarrhea diseases, because of dehydration, but simple actions like washing hands can really help. So it was very exciting. And also the other thing, you know our group we had some ladies who were mothers. So they helped us also a lot... like them they were talking about the toilet training of the baby. The old mothers when we were going around researching, they were just explaining that no, we used to train our babies using their legs, just sit he poops, but nowadays you have got these things you buy [at the chain grocery store]. Those are different tactics now.

By his account, students enjoyed both the important practical implications and connection to experience.

Thus, through the activities of the book, then, the Insofu group generated knowledge about conditions in their local community—the prevalence of certain diseases, common social and environmental conditions that contribute to the diseases, for example—and tried to use what they found to raise awareness and address some of the factors contributing to disease. In that way, activities of knowledge generation led directly into knowledge sharing; this manifestation of agency was closely linked to the previous one.

The spectrum. The examples of Elijah and Alex and their PSA groups illustrate different points along a spectrum of a third manifestation of agency—agency as generating knowledge. In comparison to agency as applying learning to practice and agency as drawing from and contributing to flows of knowledge, the spectrum of experiences that came up in interviews with regard to agency as generating knowledge was much simpler and the number of people who brought it up was smaller. Thirteen individuals mentioned examples of activities where they had generated knowledge about their local context through activities assigned by the textbooks, such as Elijah's group did regarding the

pond ecosystem. An additional eight people mentioned somewhat more in-depth research activities that involved gathering information from multiple sources and analyzing it for patterns.

Discussion

The six cases introduced above shed light on three different manifestations of science agency: agency as applying learning to practice, agency as drawing from and contributing to flows of knowledge, and agency as generating local knowledge. These are offered in complement to the instances of agency identified by Turner (2012): agency as asserting intentions, as authoring, as improvisation, and as critique. While the construct of critical science agency has developed in response to concerns of equity and representation in science education and science disciplines, it requires a few refinements when employed for purposes of framing a role for science education in community development. The examples of agency identified in this chapter have shed light on a few modifications that would make the construct more robust in the context of education for development, specifically: (a) attention to the implications of agency for life outside of the classroom, in activities that shape community development; (b) attention to the implications of agency for both individual and collective life; and (c) the idea of a spectrum of agency.

Agency Outside of the Classroom.

With regard to the first point, the instances of agency found in this chapter stand in contrast to the examples found in the literature in terms of how science agency is operationalized and the benefits ascribed to it. Most prevalent in the critical agency literature

is the framing of agency in terms of how students participate in the classroom, whether there is opportunity for their authentic contributions and influence over the classroom environment (Basu, 2008; Basu, Calabrese Barton, Clairmont & Locke, 2009; Boaler & Greeno, 2000; Tan & Calabrese Barton, 2012; Turner, 2012). These are seen to impact the likelihood that students continue to be engaged with the discipline and consider the possibility of science-related careers. Instead of trajectories of participation focused on potential science careers later in life, the instances of science agency described here have looked specifically at ways students use their science learning in their everyday lives during the course of their studies—in growing gardens, making environmentally friendly decisions in waste disposal, and sharing ideas with others. There are particular implications of this reconceptualization of science agency for thinking about community development. In contrast with a model in which the teaching of science contributes to development by raising a team of national scientists who work in national laboratories, the science agency described here is conducive of what Gitari (2012) refers to as “endogenous science.” Gitari envisions an endogenous culture of science in which “a critical mass of people” are “purposefully attempt[ing] to transform the living conditions in everyday life using the principles of the discipline of science” (p. 29). Such a description fits with the hopes of many of those mentioned in the introduction to this paper (Kyle, 1999; Ngubane, 2003; Savage & Naidoo, 2003).

From the six examples of science agency described in this chapter, we can put together a rough sketch of a model of how science agency can contribute to development in the beginnings of Gitari’s (2012) endogenous culture of science. At the simplest core, the experiences described in this chapter suggest that the study of science leads to the de-

velopment of science agency, or an enhanced capacity to act using science, and this lead to decision-making and changes as behavior that contribute to community development. As the diagram illustrates, students have knowledge from home, from previous experiences, school, neighbors, and other sources. Opportunities to study science, such as in the PSA program, offer students access to more knowledge content and knowledge resources. This enhances their preexisting capacity to act and gives rise to more actions that better contributed to community development.

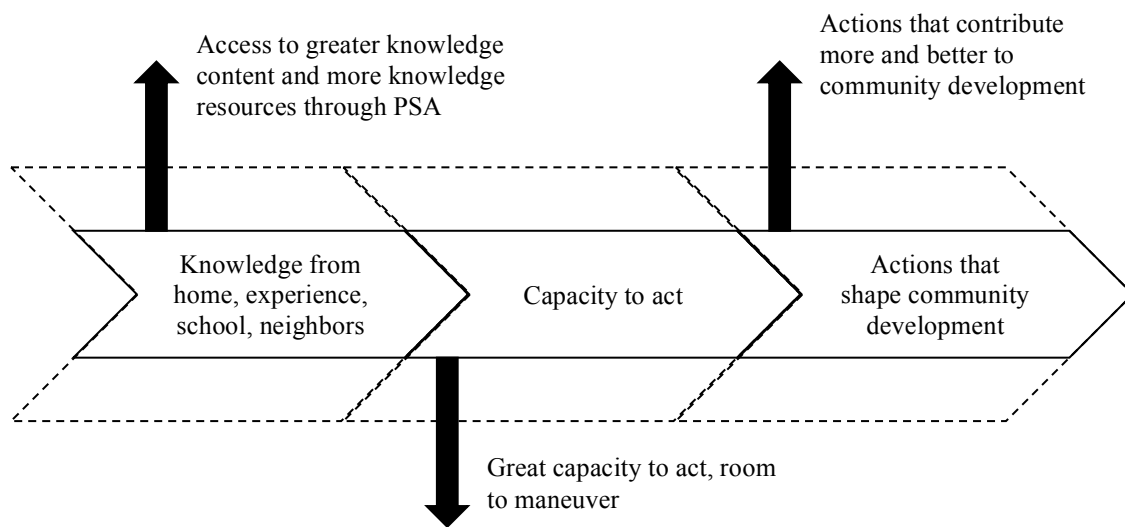


Figure 1. Simple Model of Science Learning for Community Development

This simple model can be applied to each of the six cases described in the chapter, to provide a more concrete glimpse of how science education can contribute to community development. A few examples are shared below.

Hillary

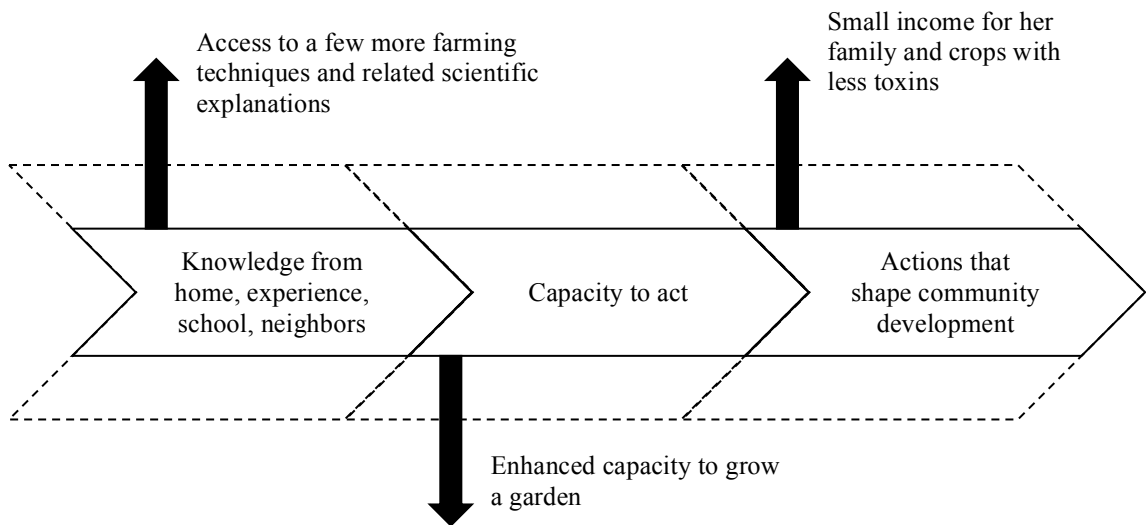


Figure 2. Simple Model of Hillary's Use of Science Learning for Community Development

In learning a few new farming techniques and the science techniques behind them, Hillary's capacity to grow a garden was enhanced. She used this greater capacity to earn a small income for herself and her family. Her family and those who bought the vegetables benefitted from crops with less toxins, and the environment benefitted by her choices to compost and avoid the use of pesticides.

Timothy

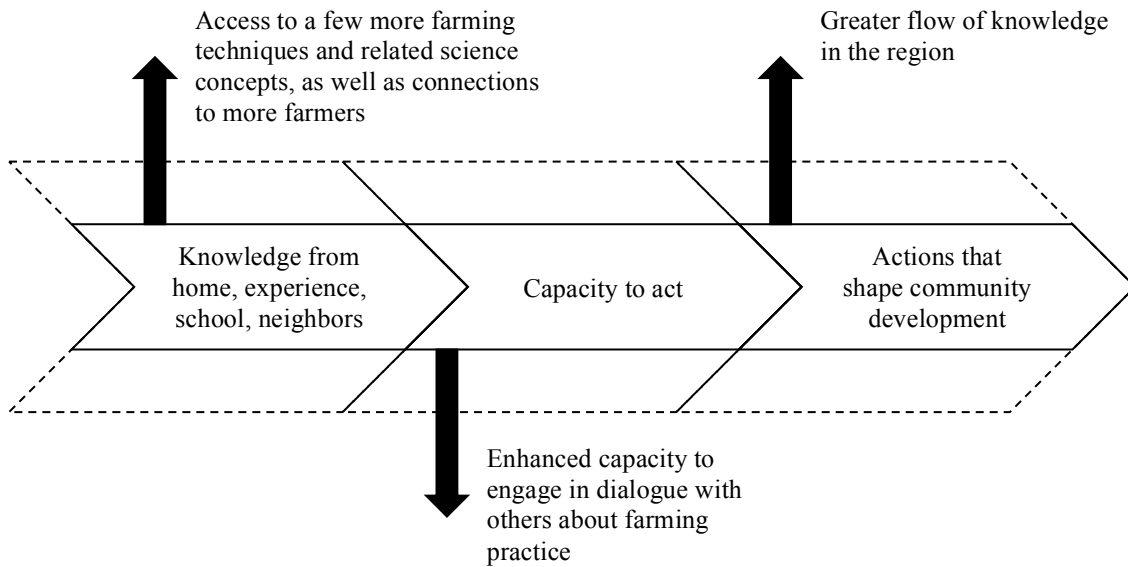


Figure 3. Simple Model of Timothy's Use of Science Learning for Community Development

For Timothy the study of agriculture in the program enhanced his capacity to engage in dialogue with others about farming practice, ultimately leading to a (somewhat) greater flow of farming knowledge in the region, as he shared what he was learning with several others and became connected to a larger number of farmers from whom he drew insights.

Alex and Insofu 1

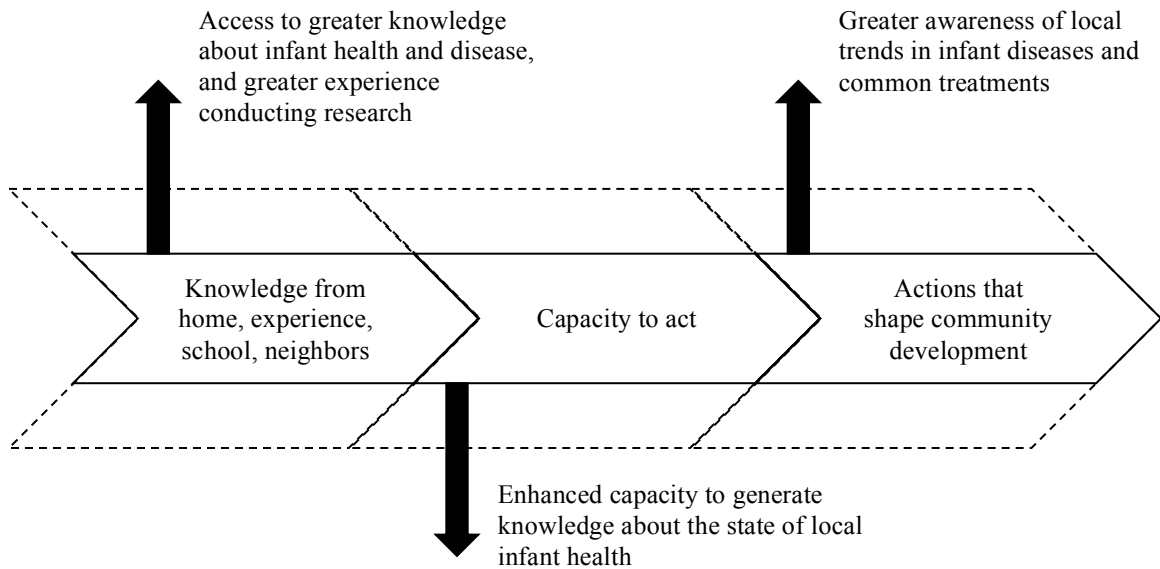


Figure 4. Simple Model of Alex and Insofu 1's Use of Science Learning for Community Development

In the case of Alex and the Insofu 1 PSA group, what they learned about infant health and disease enhanced their capacity to generate knowledge about local infant health and ways mothers treat common diseases. As they had a better sense of such trends in their community they were able to share with mothers in the region.

This review of the three examples illustrates a simple model of how science education can contribute to community development—to be taken up and further developed in subsequent chapters. For now, it emphasizes how the construct of science agency needed for an exploration of science education for community development requires attention not only to student voice in the classroom, but to ways in which students are using the science they learn for individual and collective benefit in their everyday lives.

Collective Benefits

In relation to the second adaptation proposed to critical science agency for its use in the context of community development, closer examination of the cases above allows for the opportunity to explore possibilities of agency less constrained by the individualistic patterns of thought identified at the beginning of the chapter. At the level of benefits, the science agency described here impacts both the individual and the community, as seen in the chart below.

Table 5. Individual and Collective Benefits of Science Learning for the Six Cases

	Benefits to the individual (and his/her family)	Benefits to the larger community
Hillary	<ul style="list-style-type: none"> • Ability to grow vegetables without toxins for herself and her family • Small source of income 	<ul style="list-style-type: none"> • Access to vegetables without toxins • Environment not contaminated by pesticides from garden
Alvin	<ul style="list-style-type: none"> • Ability to grow vegetables without toxins • Small source of income • Use of family plot previously considered unusable • A greater tendency to ask questions and try to understand why 	<ul style="list-style-type: none"> • Access to vegetables without toxins • Environment not contaminated by pesticides from garden • More effective rendering of electrical technician services
Mabel		<ul style="list-style-type: none"> • Infusion of ideas for practice for manufacturers and farmers
Timothy	<ul style="list-style-type: none"> • Vegetables without toxins for himself and his family • Small source of income • Use of plot previously considered unusable • Better sense of agricultural knowledge in the community 	<ul style="list-style-type: none"> • Greater spread of ideas for farming
Elijah	<ul style="list-style-type: none"> • Greater knowledge of conditions of local ecosystem 	<ul style="list-style-type: none"> • Greater knowledge of conditions of local ecosystem
Alex	<ul style="list-style-type: none"> • Greater knowledge of local conditions affecting health and ways being used to prevent disease 	<ul style="list-style-type: none"> • Greater knowledge of local conditions affecting health and ways being used to prevent disease

In the cases of Hillary and Alvin applying what they have learned to agricultural practice, we might say benefits have largely accrued to the individual students themselves. They are growing better gardens, and earning a small income. Perhaps their families also benefit from the income and the food grown, and maybe the neighbors who pur-

chase these vegetables benefit from greater access to vegetables not laden with harmful chemicals. It is at this level that the benefits of education to community development are often framed. Greater access to knowledge leads to greater economic opportunity, benefiting the individual with spillover to the community.

The cases of Mabel and Timothy, in contrast, illustrate agency that is primarily social in its benefits. Their actions strengthen flows of knowledge within the community, furthering the spread of the beneficial ideas by both sharing what they have learned and encouraging and reinforcing what they find others know. Each person participating in these exchanges has the possibility to benefit at an individual level, but the strength of knowledge flow in a community is really a collective characteristic. The cases of Elijah and Alex, and their PSA groups, are similarly collective. The topics researched, environmental health and child health, have broad collective implications. Furthermore, the research itself was undertaken by a group.

One possible interpretation of these cases would be to organize them along another sort of continuum. In this case it could span two dimensions, individual benefits and collective benefits, as pictured below. It has a certain utility in expanding thinking about possibilities for science agency. The examples of critical science agency introduced previously in the literature, for example, would arguably fit most often in the lower left corner, given that they tended to involve students shaping class projects in manners meaningful to them and considering more seriously potential science careers. The benefits were primarily at the individual level and confined to particular actions structured by classroom learning activities. Some students did engage in non-classroom spaces, for example, Neil's participation in robotics competitions (Basu et. al, 2009) and the GetCity

students' efforts to share what they were learning about urban heat islands with community members. Yet, in each of these cases benefits were confined primarily to the students themselves. The examples of Alvin, Timothy, and the others illustrate ways in which participants' growing agency can permeate areas of endeavor outside of the classroom, can be sustained beyond the duration of class activities, and can have collective as well as individual benefits.

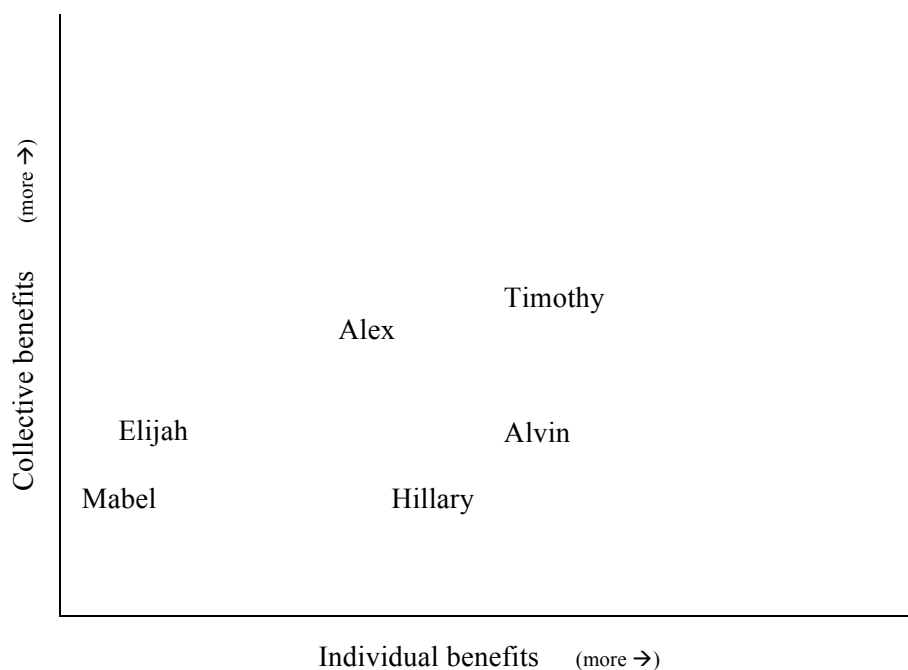


Figure 5. Two Dimensions of Benefits of Science Learning for Six Cases

At the same time, however, caution must be exercised lest thinking about individual and collective benefits becomes too linear. The experiences of these six participants, and many others, suggest that the different types of agency mentioned here are quite interconnected. Though Hillary and Alvin both spoke primarily in terms of how their study of science in PSA affected their ability to grow vegetables, their stories also include elements of sharing what they learned with family members, including her in-laws and his

uncle. Furthermore, their gardening practice was first informed by what they had learned from their families growing up. Similarly, some of the students that participated in the research about early childhood diseases were mothers themselves, and added to the research in that way, while in both of the latter two cases generating knowledge led to sharing it with others. These six examples illustrate an interconnectedness of the different types of agency identified here, with individual and collective benefits being intertwined and mutually reinforcing. In contrast to previous studies of science agency, then, the examples of agency mentioned here link it not only to individual change but collective change as well.

Agency as a Spectrum

Finally, the idea of a spectrum was helpful in accounting for differences in the ways in which participants demonstrated the same type of agency. Conceiving of agency in terms of a spectrum reflects the reality that not all students will take away the same things from a learning experience. The forward movement of a collective entails the movement of individuals at different paces. And students will naturally connect to different elements or find value in different places. However, a common content unites students around the same set of ideas and practices. Though the agency they demonstrate as a result of science study will not take the exact same form for each student, the manifestations of agency captured here represent different points along a common path, the direction of which is shaped by the vision of the program itself, described below.

Structure and Agency

In addition to the above three modifications to the notion of science agency employed here towards ends of community development, the examples mentioned here highlight an interesting interplay of freedom or personal choice and constraint. While they the ways that participants used science do reflect their tastes to a certain extent, for example the widespread interest in agriculture, the six accounts explored here move beyond orientations to agency that emphasize exerting personal preferences to highlight instead a growing capacity to act as a result of science study. The cases are not simply the product of enhanced freedom on the part of individuals. Rather, certain social structures and restrictions have fostered this greater capacity to act.

For instance, rather than projects in which students chose activities that reflected their own interests—the way Donya created a debate activity because of her interest in becoming a lawyer (Basu et. al, 2009) or another student, Angel, created a math project that communicated the inadequate size of the girl’s bathroom at the school because of her personal frustration with the issue (Turner, 2012)—the content in the PSA program was mostly predetermined. All students studied all the textbooks and tried to carry out all the activities assigned within them. In this way, they were all exposed to the same content related to agriculture, environmental protection, family health, and atomic theory; they did not get to choose between these. They were all responsible for speaking to local farmers, mothers, small manufacturers, and others, as the textbooks assigned. Such constraint was important in the individual and collective development of experience and ability. Yet, as the next chapter will explore in greater depth, the experience was empowering to participants, opening up possibilities for action rather than limiting them.

In this way, the six cases above begin to highlight how agency, as an educational product intended to contribute to social good, was not simply a matter of what dimensions of scientific knowledge attracted students most or which they found most useful. It resulted from the fact that students were more capable of growing better gardens, of seeing new possibilities for action and persevering in figuring out solutions, of benefitting from others' knowledge and sharing what they learned, and of generating new insights. The next chapter will offer a more in-depth look at what contributes to the development of capacity to act in this context, but for now, it seems evident that something about what is studied and done in the structured lessons, along with students' own choice and interactions with that structure, fostered the types of agency described above. The next chapter will also provide an opportunity to examine some of the philosophical underpinnings of the program.

In considering science agency in a manner that aims to move beyond some of the trappings of individualism, this chapter seeks to contribute to a discourse on education for development by offering glimmerings of alternate paths. Utilizing the construct of critical science agency in a manner centered on the individual runs the risk of an exaggerated celebration of individual freedom. For example, in recounting instances of critical mathematics agency, Turner (2012) describes two boys who made a video of an alternate reality in which their desire to have the polls in the middle of the gym removed was actually possible. Though the project included very little math, Turner describes this as an instance of agency because they "authored" their own reality and refused to submit to ways that their teacher suggested they might include math in their topic of interest. Yet, in what ways does such agency contribute to community development? To what kind of

community does it contribute? Are these boys more capable of something at the end of their study? To what extent can freedom of choice as an end in itself be potentially disempowering? From an alternate but related perspective, sole attention on individual agency in education for development, to the exclusion of structure, runs the risk of exaggerating the individual's responsibility for his or her own plight. This is particularly dangerous in the context of development. Approaches that seek to develop capacity on the part of the individual with little attention to larger social forces and structures are either naïve or insincere in their desire to contribute to change. Agency as enhanced capacity to act serves notions of education for development by potentially tempering some of these tendencies. Greater consideration for the relationship of the individual and collective in the science agency developing in the PSA program in Zambia are pursued in the next two chapters.

Conclusion

In order to be of use in considerations of social transformation via community development, the notion of critical science agency must take into consideration more than the mere capacity to articulate one's own preferences or seeing possibilities of a career in science. The notion of agency considered here sets the stage for looking at how such agency is developed in figured worlds, specifically the connection between conceptions of knowledge and the development of agency.

CHAPTER III

CONCEPTIONS OF KNOWLEDGE AND SCIENCE AGENCY

Following the line of thinking of previous chapters, in which critical science agency is adopted as a construct to help make a more concrete connection between science education and community development, this chapter takes up the question of what contributes to the development of critical science agency. If the construct of science agency aids in orienting some of the intended outcomes of science education in the context of development, the question of what contributes to achieving those outcomes becomes a valuable question.

The instances of science agency identified in the previous chapter featured efforts in the areas of farming, environmental protection, and family health, specifically in the actions of applying learning to practice, contributing to flows of knowledge and generating new knowledge. To achieve these aims, development projects or educational endeavors might be designed that offer greater access to certain information or aid in the development of particular skills, including sustainable farming techniques, information about the environmental damage caused by plastics and even techniques of the ‘scientific method’ by which students might investigate the comparative merits of particular farming techniques. Yet, such projects do not always achieve their intended aims. Projects sometimes carry with them particular values and assumptions that contradict local worldviews. In this light sociocultural theories, which consider learning as constituted by practice, with implied meanings and values, offer a means for thinking about the types of consid-

erations—beyond particular skills and information—that are important for the development of critical agency. Such theories are explored in more depth below. They have shaped the discourse around science agency and suggest the value to education for development of considering values and meaning around questions of knowledge, power, the role of the individual society, among others.

This chapter, then, pursues the question of what contributes to the development of science agency in the PSA program from a sociocultural perspective. Specifically, it takes up one particular element of the worldview within the program—the conception of knowledge—and follows the shape that that concept takes in action in the study and practice activities of the program. Then it examines the implications in the manifestations of agency identified in the previous chapter.

Meaning and Agency in Communities of Practice

Sociocultural theories in education are distinguished by the emphasis they place on the social and cultural context in shaping the learning experience. Within science education, a sociocultural perspective sees both science and the formal study of science as human activities occurring within institutional and cultural frameworks (Lemke, 2000). Research from this perspective is particularly attentive to the role of social interaction in science learning, with an eye toward the tools in communities and institutions that facilitate making sense of and to one another—language, pictorial conventions, belief systems, value systems, and specialized discourses and practices.

In science education research from a sociocultural perspective, the construct of identity has taken on particular importance. According to Sfard and Prusak (2005, p.15,

quoted in Yee, 2012), identity is the “perfect candidate for the role of ‘the missing link’ in the ... complex dialectic between learning and its sociocultural context.” Attention to identity—as both the student’s sense of self and how she or he is recognized by others as a particular type of person—has been considered key to conceptualizing the experiences of students in the social act of learning. Identity research responds to concerns, particularly in science education, for issues of fairness, representation and access to the domain of science in school and in career paths (Gee, 2000). It is taken up both with regard to identities made available at the micro-level in the classroom, and broader macro issues of power and structure.

The discussions of agency in science education research have been intertwined with the research and discourse on identity. In many ways, considerations of critical science agency are just an extension of that conversation with particular outcomes in mind. For example, Calabrese Barton and Tan (2010) describe, “agency is at once the possibility of imagining and asserting a new self in a figured world at the same time it is about using one’s identity to imagine a new and different world.” Calabrese Barton, Tan, and many others looking at identity and agency in science and mathematics education have framed their research with the theories of anthropologists Holland, Skinner, Lachicotte, and Cain (1998) in the book *Identity and Agency in Cultural Worlds*.

According to Yee (2012) part of the appeal of the framing of identity of Holland et. al is that it accounts for both free will and structural constraints as individual circumstances intersect with evolving social contexts. Through collectively realized cultural worlds, persons are formed and form. These worlds, which they refer to as “figured worlds,” are characterized by the meaning made within them: “By ‘figured world,’ then,

we mean a socially and culturally constructed realm of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others” (Holland et al., 1998, p. 52). In figured worlds, identities are fashioned through the practices implied by participation. Particularly consequential are “positional identities” that establish individuals’ location within day-to-day relations of power, deference, entitlement, and affiliation. From the vantage point of these identities, individuals author responses to the social structure of figured worlds, drawing on and responding to the meanings and patterns of action of that world. In one example Holland provides of field research in Nepal, a woman from the lowest caste climbed up the outside of a house and entered through the balcony in order to avoid the prohibition of lower castes sullyng the place of cooking on the first floor. This was not a common practice, but an improvised response to the constraints of the figured world that suggested to the authors both a desire to do right by the moral and cultural world in which she participates and the use of social meaning for personal ends—in other words, a stance that draws on both culturalist (which sees people as upholding cultural structures) and constructivist (which sees people as maneuvering within and negotiating with those structures) positions. In this example, and in the use of the construct in general, an effort is made to account both for micro-level interactions of specific communities and the forces of the macro level dynamics of race, gender, caste, and economic state.

Research on learning has extended the application of the construct of figured worlds to communities and groups within which learning takes place, both out of school and within the classroom. For example, Boaler and Greeno (2000) assert that the class-

room learning environment itself, around a particular subject matter, could be considered a figured world:

A mathematics learning environment could be regarded as a particular figured world because students and teachers construct interpretations of actions that routinely take place there... The importance of this label for researchers of mathematics education resides in the characterization of a mathematics classroom as an interpretable realm, in which people fashion their senses of self. Figured worlds draw attention to interpretations by actors—students and teachers, for example—and to the rituals of practice. The mathematics classroom may be thought of as a particular social setting—that is, a figured world—in which children and teachers take on certain roles that help define who they are. (p. 173)

Applying the concept of figured worlds to the classroom allows Boaler and Greeno to interpret the actions of students and teachers as resulting from their understanding of the affordances and constraints of those worlds. Similarly, researchers have explored out-of-school learning environments, such as extracurricular activities (e.g. Nasir & Cooks, 2009), as figured worlds, as a means of understanding factors that contribute to learning. Often in these studies, there has been an explicit or implicit comparison to learning in the classroom, the thinking being that understanding the nature of learning in informal settings might shed light on how to improve formal education (e.g. Nasir & Hand, 2008). Within these studies, the central question has been one of identity development and how the roles they adopt shape levels of engagement and possibilities for action.

The studies that have examined informal and formal learning through the lens of Holland et al.'s 'figured worlds' have in part looked at what contributes to the development of agency, largely through attention to identity development. A look at a few key studies in this regard will set the stage for the exploration of this chapter.

In the aforementioned study, Boaler and Greeno (2000) examined the dynamics of the figured worlds of AP-calculus classrooms in six northern Californian high schools

through interviews with 48 students. Through these interviews, they found two kinds of figured worlds with a difference between them that was key for agency development. In four of the six classrooms, students described a figured world that was “individualistic” and “highly ritualized,” in which “students come to class, watch the teacher demonstrate procedures and then practice the procedures—alone” (p. 177). In the other two, student descriptions conveyed themselves as “active agents in their classes,” discussing questions with one another and “contributing to the shared understanding of ideas that developed among the class” (p. 178). Within these two different types of figured worlds, students identified different positions for themselves. In the former sorts of classrooms, students emphasized the existence of right answers, and described their role as absorbing knowledge from teachers and textbooks in order to reproduce the necessary procedures, with little or no thought, to reach those right answers. In the latter type of classrooms, students considered themselves active learners who did more than memorize; they had to think deeply, and they considered their relationships with one another to be an important element of the classroom. The positional identities that students described related to their tendency to enjoy mathematics and to consider continuing with mathematics in the future. In classrooms with little discussion, roughly half the students described liking math and planning to continue studying it; those who did, described appreciating the certainty that they perceived in it. In the other two classroom, a clear majority (80-90%) of students reported liking math and planning to continue their study in math. Ultimately, Boaler and Greeno found the construct of figured worlds useful to framing students’ experiences in mathematics classrooms and how these might relate to decisions to continue

the study of mathematics in tertiary education and possibly take on careers in mathematics. A key piece of their argument can be summarized as follows:

The figured worlds of many mathematics classrooms, particularly those at higher levels, are unusually narrow and ritualistic, leading able students to reject the discipline at a sensitive stage of their identity development. Traditional pedagogies and procedural views of mathematics combine to produce environments in which most students must surrender agency and thought in order to follow predetermined routines. (Boaler & Greeno, 2000, p. 171)

This study is of particular interest to the topic of this chapter. Boaler and Greeno's interviews with students suggested the environment of the classroom shapes how students connect to the discipline and see themselves potentially continuing with it. Having an opportunity to take on a role of 'active agent' and contribute to the shared understanding of ideas correlated with a much more prevalent desire to continue with mathematics. This chapter explores how similar opportunities and orientations in the classroom might relate to how students use their learning about the discipline—in this case, science—outside of the classroom. At the same time, the research and analysis employed by Boaler and Greeno generated a dualistic account that ultimately highlighted 'good' and 'bad' approaches to teaching mathematics. The strength of the rather simplified vision it provided was that it made clear the potential implications that classroom dynamics had on identification with the discipline and plans for future use. In service to these ends, some of the complexity of experience within these classrooms was likely lost.

Along similar lines, Nasir and Hand (2008) compared opportunities for engagement in high school mathematics and high school basketball for two students through interviews and video recorded observation. In the study, the engagement supported by the practice of basketball was deeper since both students had greater access to the domain,

were able to take up unique roles integral to the practice, and found ways to express themselves and feel competent. In contrast, the mathematics classroom made such opportunities available for only one of the students. Differences in the level of engagement afforded students also affected the development of practice-linked identities. While both students expressed and displayed strong practice-linked identities in basketball, the same was not true in the mathematics classroom. One student's connection to the class was more focused on getting good grades and being a good student than about a math-related identity, the other consistently struggled to find ways to insert himself productively into the practice.

In a later study, Nasir examined some of the resources that affect the development of such practice-linked identities (Nasir & Cooks, 2009). Taking the case of high school track and field, she and a colleague identified three types of identity resources that seemed to affect whether students remain at the periphery of a community of practice or advance toward fuller participation: material resources of the physical environment (for example, use or not of starting blocks), relational resources (with other members of the team and with the coach), and ideational resources, ideas about oneself and one's relationship to the practice.

The research of Boaler and Greeno (2000), Nasir and Hand (2008), and Nasir and Cooks (2009), among others, suggests a certain value in utilizing the notion of figured worlds to conceptualize the development of agency and think about ways that learning in the classroom can affect decisions and behavior outside of the classroom. In a given learning environment, students and teachers take up certain roles that reflect a particular configuration of meaning and practice. There are shared language, values and beliefs,

and patterns of action—structures that shape action and are in turn shaped by the ways participants in the program choose that semiotic system of meaning towards their own ends. This shifts education for any sort of meaningful collective development or social change beyond imparting skills and information to consideration of entire systems of meaning and how they impact action.

It is worth revisiting the topic of structure and agency. Holland et. al (1998) have posited an account of social interactions that gives attention both to the ways that systems and structures larger than the individual, often existing prior to the individual, play a key role in shaping her or his actions, at the same time that it shuns determinism, considering the individual to have a certain level of agency in utilizing the tools of the figured world for their own purposes. Yet, this ‘dialectic’ description of agency and structure still seems to pit the two against one another in a zero-sum way. A certain proportion of a person’s actions are determined by the social context and a certain proportion reflect his or her assertion of self in the face of that context, bending it to his or her will. Such an orientation offers little space for ways that structures can open up capacity to act, as described in the previous chapter, and ways that individual agency might imply not pursuing one’s own preferences out of deference to the common good. The vision of agency taken up in this paper is as ‘capacity to act’ or ‘room to maneuver,’ not against the imposition of social structures but rather in comparison with a position of less room to maneuver—out of ignorance, lack of know-how, failure to see possibilities, as well as limiting beliefs or patterns of action. It does not imply the need to limit the influence of structure over the individual, but rather to engage the individual in contributing to structures that

allow for greater maneuvering in a more beneficial manner, at the level of individuals, institutions, and communities.

In general, one might argue that Holland et. al's account of identity and agency in figured worlds provides a broad overview of rather basic and largely agreed upon ideas, that context shapes behavior without eliminating free will. Its contribution, of value to this study, is the role of shared meaning and practice in accounting for this practice. The notion of figured world is employed here as a sister conception to Lave and Wenger's (1991) communities of practice, as described in chapter one. In both cases, learning is viewed primarily from the perspective of social practice among a rather well-defined collective engaged in shared practice. The meaning and values enacted in the community are key to understanding participants' engagement in learning processes and the possibilities for action that emerge there from. Typically in literature on critical science agency, identity has been the entry point to understanding the figured worlds of the classroom and their impact on agency. The result has been particular emphasis on student belonging and engagement in the classroom and the impact of these on career trajectory. Such concerns are important in the context of inquiries regarding why representation along the lines of race, gender, and economic background in the sciences has been so disproportionate, but is less pressing for thinking about science education in the context of community development. Emphasis on identity, engagement and professional trajectories have downplayed the value of considering the content of science study, focusing more on the environment.

In this chapter, rather than focus exclusively on identity at the individual level and create, for example, a typology of identities and their implications for critical science

agency, the community of practice as a whole is taken as the unit of analysis. Attention is directed not only at the identities enacted by students and tutors, but also at the relationships among actors, the language and patterns of action, and the shared values and beliefs of the community of the community of practice—all this in relation to a single element of the figured world, its orientation to knowledge. The purpose in this approach is to move beyond some of the limitations of focus on the individual to capture something of the collective experience within the classroom and some implications for that learning outside of the classroom.

This chapter examines the intersection of figured worlds and agency, through attention to conceptions of knowledge in the classroom and in students' use of science outside of the classroom. In so doing, it draws from the discourse around epistemology and science education, discussed in the next section. Before getting into that discussion, it should be noted that sociocultural perspectives are only one way of conceptualizing how education can contribute to an expanded capacity for action. Choosing this lens to think about agency offers certain benefits, including consideration of social influences on the individual, the collective as something more than the amalgamation of various individuals, and the connection between social practices and beliefs, values, and understanding. In looking at culture and social practice, less attention is paid to the role of cognition, mental models, and understanding in greater capacity to act. Furthermore, speaking at the level of meaning and values has the potential to imply that the conceptions of knowledge are a matter of taste or incidental preference of an educational approach, rather than the result of thoughtful consideration and an effort to read reality accurately on the part of those forging the approach.

Epistemology in Science Education for Community Development

A look at considerations of knowledge in the PSA program can be framed by the conversation around epistemology and science education. Epistemology is a branch of philosophy concerned with the nature and scope of knowledge. While some sort of orientation to the nature of knowledge is implied in any approach to science teaching and learning, there are a few distinct ways in which epistemology has been explicitly addressed in science learning research. Kelly, McDonald, and Wickman (2012) identified three such ways. Some studies, they describe, take a disciplinary perspective, examining the nature of evidence and the criteria for theory choice as they vary between academic disciplines. Others focus on the personal epistemological views of each individual, looking at students in particular, and explore how these influence learning. A third group looks at the ways social practices determine what counts as knowledge in particular local contexts.

Both of the latter two areas of inquiry offer insights relevant for the purposes of this chapter. Research on the personal epistemologies of students has described a few dimensions of students' epistemological orientations and has begun to explore ways these views influence learning. Two of the dimensions most prevalent in such research are taken up here as primary means for investigating the elements of epistemology found in the PSA program. Research that examines epistemology as constituted by social practice fits with the conception that meaning and values are forged within communities of practice and provides valuable tools for inquiry into students' epistemology. An overview of each of the two areas of research will set the stage for this study.

Personal epistemology research traces back to the work of William Perry (1970). Interested in the different ways students seemed to respond to the pluralistic environment of the university, Perry gave a questionnaire about educational values to 313 undergraduate students, then followed up with 31 of them in interviews about their experiences in university. From this data, Perry and his colleagues constructed a model with nine positions of ‘intellectual and ethical development’ that captured evolving beliefs about knowledge. Broadly speaking, these nine positions fell into four categories: (1) *dualism*, in which beliefs are characterized by an absolutist, dualistic, right-wrong view of the world where authorities know the truth and convey it to others; (2) *multiplicity*, a modified version of dualism, in which authorities may sometimes disagree if they do not yet know the answer or if the topic is one that lies outside the realm of authority; (3) *relativism*, wherein knowledge is considered to be contextually based and one must take on a more active role in making meaning; and (4) *commitment with relativism*, where the individual additionally affirms strong commitments to particular values (Hofer & Pintrich, 1997).

The initial vision of epistemological development proposed by Perry was taken up and reworked by several subsequent researchers, who forged distinct models of epistemological development based on their own interview and survey research (Hofer & Pintrich, 1997). Belenky, Clinchy, Goldberger, and Tarule (1986), for example, drew from interviews with 135 women to generate a series of development “positions” that reflect Perry’s development structures: in the *silence* position, women conveyed a voiceless and passive existence in the face of authority; in the position of *received knowledge* the women reflected either-or thinking characterized by one right answer where knowledge is

considered to originate outside of the self; in the *subjective knowledge* position, the women see themselves as the source of knowledge rather than external authorities, though knowledge is still considered dualistic; in the position of *procedural knowledge*, the women use systematic analysis and reflection, either through separate, impersonal knowing or connected, empathetic knowledge. Along similar lines, King and Kitchener (1994) examined the epistemic assumptions that underlie reasoning, looking at both the nature of knowledge and how knowledge claims are justified. *Pre-reflective stages* involve high levels of knowledge certainty; knowledge is generally considered concrete, absolute, and known by authorities. *Quasi-reflective stages* gradually incorporate room for uncertainty; authorities do not always have correct answers and each person is considered to be entitled to his or her own opinion. In *reflective stages*, knowledge is understood contextually and the knower actively constructs meaning.

These and other models (e.g. Baxter Magolda, 1992), like Perry's model, characterized individuals' epistemological beliefs in terms of stages. Though the names and details of the stages varied among the research, they map loosely on to one another, progressing from simple, certain, and dualistic beliefs of right and wrong, through relativist and uncertain subjectivity, and ultimately arriving at beliefs that allow for multiple views whose validity can be considered within a particular context (Hofer & Pintrich, 1997; Kelly, McDonald, & Wickman, 2012). Underlying the developmental path articulated in these categories are particular conceptions of what constitute valid sources of knowledge and to what extent knowledge is considered certain. These two topics are used as entry points to understanding the conceptions of knowledge underlying the figured worlds of PSA in Zambia. In each of these cases, the researchers envision epistemological beliefs to

progress from simple stages, in which knowledge is considered certain and dualistic, known by external authorities and conveyed to learners, to higher stages in which knowledge is considered more context-dependent and in which learners have a more active role in making meaning and generating knowledge. Like other developmental models, such as Kohlberg's (1969) six-stage model of moral development, whose shortcomings were identified by Gilligan (1982), these models could arguably be seen as taking a normative stance that ultimately identifies the epistemological position of the researchers themselves as the highest level to which students and others gradually advance.

Others operating within the same research vein, particularly Schommer (1990), have considered epistemological beliefs not from the perspective of linear development along a single trajectory, but rather as "composed of several more or less independent dimensions" (1990, p. 498). These she explored in their relationship to academic performance. Through questionnaires and a writing assignment for 166 college students, Schommer found that belief in "quick, all-or-nothing learning" on the questionnaire correlated with oversimplified conclusions and an overestimation of how well they understood the passage; and belief in certain knowledge correlated with absolute conclusions. From these findings, she suggests that epistemological beliefs seem to affect the way one processes information and monitors one's own comprehension.

The present study seeks to examine the epistemological beliefs embedded in an educational program that places science learning in the context of individual and collective development. As such, it does not set out to clarify the ambiguities in competing epistemological development theories, but rather draws from their commonalities to explore what those beliefs look like in this particular context and how they relate to the ac-

tions taken by students. In so doing, it draws upon Schommer's (1990) vision of multiple independent dimensions of epistemological belief, rather than a single trajectory. The dimensions have identified are two most commonly addressed in the literature: certainty of knowledge and source of knowledge.

While focused on dimensions of epistemological belief identified in personal epistemology research, this study takes an approach more in line with researchers who have explored epistemology as an element of social practice rather than personal belief. Such an approach draws, in part, from the contributions of social studies of science that have examined science itself as a social practice (e.g. Knorr-Cetina, 1999; Latour, 1987).

In one study, Lidar, Lundqvist, and Ostman (2006) looked at student-teacher interactions in a seventh and eighth grade classroom in a public school on the outskirts of a town in Sweden to understand how teachers communicated epistemological ideas as they supported students in classroom science experiments. To do so, they introduced the notion of "epistemological moves" as a unit of analysis and defined them as "specific moves in a language game that communicates to the students what counts as knowledge and what counts as relevant ways of acquiring knowledge in this particular practice or situation" (Lidar, Lundqvist, & Ostman, 2006, p. 153). For example, two students explain to the teacher what they observed, then in her response she confirms that they are doing a valid experiment and have observed what they were supposed to. Lidar et al. refer to this as a confirming epistemological move. From their research they identify five types of moves: *confirming moves* that let them know they are on the right track; *re-constructing moves* that encourage them to recognize the things they have noticed as important to the topic at hand; *instructional moves* that direct students to take certain action;

generative moves that summarize important elements of the experiment so that student may generate explanations; and *re-orienting moves* that prompt students to move in another direction with the experiment.

While the study in this chapter is oriented around insights from both personal epistemology research in science education and research that examines epistemology as an element of social practice, it is important not to conflate the two approaches as essentially the same. They are built upon quite different premises. Like many other strands of psychology and education research emerging around the same time, personal epistemology research tends to take a normative, developmental view of students' epistemological perspectives, envisioning a single trajectory along which they progress from simple or incorrect epistemological beliefs to more complex and appropriate ones. Those working from a social practice perspective are less concerned with identifying the epistemological beliefs of individual students, considering these likely to change for a given individual depending on the practice in which he or she is engaged. Instead, the meanings and values implied by actions (including speech as an action) are valued over self-professed beliefs. In the former type of research, statements on a questionnaire judged on a Likert scale and interview questions asking directly about beliefs are important means of gaining access to an individual's personal epistemology. In the latter, ethnographic studies of the interactions of various individuals in context shed light on the epistemological orientation of a particular practice.

In the case of this study, however, personal epistemology research is drawn upon as a means of identifying key themes in the implications of epistemology for science learning. Specifically, it directs attention to the topics of knowledge certainty and

sources of knowledge, including the way a person sees him or herself in relation to those sources. Yet the perspective taken in this study is more in line with the social practice perspective, where attention is given to the meaning woven into the interactions of a community of practice.

Approach to Research

This chapter is dedicated to exploring the following two questions regarding epistemological belief and agency in the PSA program:

- (1) What are the predominant epistemological beliefs in the figured world of PSA in Zambia?
- (2) How are these beliefs manifest in instances of critical science agency demonstrated by participants in the program?

In order to get a sense of the epistemological beliefs woven into the figured world of PSA, attention was paid to considerations of knowledge and learning from four sources:

- (1) *Participants' impressions of the program, particularly in their early experiences with it and how they see it in comparison to other experiences.* Those interviewed were asked questions such as the following: How did you come to hear about the PSA program? What do you remember from your study of the first few books? Flip through them and mention what stood out to you in that study. In what ways was it similar or different to school or other experiences? In these conversations, students and tutors identified a number of what they saw to be defining characteristics of the program, many of which related to the nature of knowledge. The ap-

proach to data analysis for interviews was to read through all interviews and code all those comments related to knowledge and their learning experiences.

- (2) *Efforts to guide and train new tutors.* During the ethnographic research, five men and women began working as tutors with new groups of students. The orientation they received to their work during tutor meetings, and their reflections during interviews on what contributed to their capacity to tutor, provided another means of understanding meanings important to the figured world. In this case, the data drew from approximately 60 hours of participating in tutor trainings, about 16 hours of participating in weekly tutor refreshers, complemented with tutor accounts in interviews about their formation. Within this data, attention was paid to comments about sources and certainty of knowledge, and these were coded for themes.
- (3) *The textbooks.* The textbooks were examined to understand the epistemological ideas they explicitly and implicitly convey. Specifically, the books were analyzed in terms of (a) all the places where characteristics of knowledge are explicitly identified in the text, including statements made in the 'To the tutor' section that shed light on the logic underlying the textbook content; and (b) an analysis of the exercises of the text.
- (4) *Classroom interactions.* As a part of the field research of the study, classroom participant observation was concentrated on two PSA groups over the course of study of several books. Some of the field visits included audio-recording of the lessons (a total of roughly 12 hours) while others were captured in detailed field notes.

From these four sources, a few prevailing elements of the epistemological orientation of the figured world were identified. Specifically, the questions asked of the data to determine the epistemological dimension of the PSA figured world were the following:

- *Sources of knowledge.* What sources of knowledge are considered valid within the figured world? Which are particularly valued? What characteristics of a knowledge source contribute to its value or validity?
- *Certainty of knowledge.* To what extent is knowledge considered certain? What are the implications of this for how participants' see their own relationship to knowledge?

After the in-depth ethnographic exploration of conceptions of knowledge in the figured world of PSA, the next section examines cases of critical science agency to identify ways in which these conceptions shape participants' capacity to act. The cases are grouped according to the manifestations of agency identified in the previous chapter: agency as applying knowledge to practice, agency as contributing to flows of knowledge, and agency as knowledge generation. Looking at how conceptions of knowledge are woven in them allows for a vision of connections between conceptions of knowledge and agency.

In this exploration, the self-accounts of students, tutors, and graduates play a central role. As in the study of Boaler and Greeno (2000), respondents' description of their own experiences shed light on their interpretation of their experiences. Specifically, they wrote, "We consider students' talk about their mathematics learning in their interviews with us as reports of their perceptions and understandings of the figured social worlds of

mathematics education in which they participated as learners. The students' descriptions may also be taken to indicate their positionings in the ecologies of participation in practices of mathematics education and reflections of their authoring of identities as learners and performers of mathematics," (Boaler & Greeno, 2000, p. 174). In this case, students' and tutors' accounts of their efforts provide a view of the figured world of the PSA classroom and the influence that that world may have on students' activities outside of class.

The sections below examine conceptions of knowledge sources and knowledge certainty in the figured world of PSA, as a first step in exploring the connections of these to agency.

Sources of Knowledge: 'The goodness is that we share ideas'

At the first meeting of the Amenshi 2 group, students arrived at the community library one or two at a time. They took seats in the shade of the building, as a young man in a collared print shirt explained that they were waiting for more of their friends to arrive before beginning. Once numbers reached about ten, they picked up their chairs—old-fashioned desk-chair combinations brought out from the library—and assembled them in a circle under a tree. Junior, the young tutor who had been orienting everyone, passed out workbook textbooks. After a brief introduction, study of the first lesson began. Students took turns reading, and after each paragraph, Junior had them stop and asked questions about what they understood. "What do we mean by community here? What is your community?" When a few responded, he encouraged others to share by asking, "What else? What else?" Later, during a lull in the comments, he offered remarks such

as, “Everyone is free to share” and “If we have any difficulties, we are here to help. It’s not like other programs, where if you have difficulties you are alone.”

With these phrases, Junior oriented the students to the new setting of their program of study. In this space, multiple voices were valued over one. After one student provided an answer, others were asked to add their thoughts as well. In this space, students were expected to see themselves as helping one another to understand. Such characterizations of learning in PSA were reoccurring in how participants described the program. For example, one student (Amenshi 1F) explained in an interview:

K 1F: The goodness is that we share ideas. Maybe it was going to be difficult if we do it individually, but the way we learn them, I think we are comfortable.

EL: (*Trying to understand in the context of the lesson before the interview*)
So you share your answers in math or what do you share?

K 1F: We share the answers, like the way we were doing it. I will do the question, you will do it. Someone will do it. Not until we come up with one answer. You will find that it is a simple plus [addition problem], but you will get the different answer, you will get the different answer. So if we go there now, we calculate it together, then you will say, oh, so I went wrong there.

For this student, sharing answers was valued because it allowed for better understanding, for recognizing the cause of mistakes and fixing them. A graduate of the program (Kolwe 1M) characterized the program in similar terms, setting it in contrast to his experiences of school learning:

[In school] all we could be taught was something that is just direct. As long as they teach what is in the plan, in the lesson plan, then you forget. No concentration. But in PSA where you have, it was a thing where maybe you could like discuss, yeah, so that was the only thing where the difference was also. In PSA we could discuss and there where you’re not clear, you are able to open up and try to ask, so that you are helped by the group.

Junior himself considered this practice of encouraging the students to share ideas to be key to the program's appeal. In an interview, he described:

I think maybe what makes them [the students] to love the material is the way we do facilitate, because I'm saying so because most of them when we are learning, we learn, we learn, we learn, we learn, then they start saying: 'I think the problem we had at school is the way they were teaching us, because there they just used to come, they teach, they teach, they teach without even giving us room maybe to explain some of the understanding that we have gained. And also our contribution if they can also value it.' So they said, 'That's the reason why we didn't, we even used to fail the school, because we are not given an opportunity to express ourselves.' So I think it has been one aspect contributing to the love of the materials.

In emphasizing that multiple students should share their ideas on a given topic, two conceptions about sources of knowledge were stressed: first, that an individual's experience and outside knowledge were important sources of knowledge and, second, that consulting multiple sources was often preferable to relying upon one. Both of these were reoccurring in the figured world. These two points are explored in greater depth in the paragraphs that follow.

Students as Sources of Knowledge

Several comments of participants in the program, like those mentioned above, suggested that they saw themselves as valid sources of knowledge in the environment of the program. Along these lines, a tutor (15F) declared:

One thing I can say of PSA that is different than what I expected is that they are not just telling you things. These books they are asking you questions so that you will know from your own life.

Similarly, some participants considered their study of particular texts to strengthen their vision of themselves as sources of knowledge. One graduate (Lubambe 1F) declared:

The study of “Heating and Cooling” to me was so nice. It made me to think there are some things I can just know to myself. Like scientists, I observe things. I can make theories of what I see.

Such conceptions can be traced back, in part, to the PSA textbooks and the questions tutors asked during their study. As the Kanini 2 group studied “Environmental Issues,” for example, the text repeatedly called upon them to answer questions on the basis of their own experience. The following excerpt of field notes describes the study:

After a review of what they discussed the day before, the tutor asked one young woman to begin reading from Lesson 2. The lesson instructed them to “make a list of environmental problems with which you are familiar and explain for each how it arises and who is most affected by it.” An older woman was quick to answer, ‘lead pollution in the soil,’ to which others made sounds of agreement. Such pollution was caused by mining and was known to particularly affect young children and those living close to the mine. After a long pause, when the group seemed to have trouble coming up with other examples, the tutor encouraged the group, saying:

‘What else? Surely, you have seen many things. Where is there pollution in our microregion? What environmental problems have you observed?’

The group added to the list: air pollution caused by factories, water pollution caused by factories, and the flooding of nearby dirt roads in rainy season caused by lack of drainage methods.

In answering these questions, the students drew upon their own observations of the environment around them. The same was true in the next lesson, the following day, when the text called for them to name as many different forms of transportation as possible, identify which were common in the microregion, and describe the possible effects on the environment of several of them. In addition to answering questions on the basis of their observations, they were instructed to analyze patterns.

The tutor asked, ‘What do you notice in these answers? What patterns do you see?’ Students provided the following answers:

‘Those ones that use an engine, like cars and airplanes, always produce air pollution from the gasoline.’

‘I was seeing that each of these methods have an effect on the environment. Even walking can cause the plants we walk on to be killed. Over time, walking on the same place makes a path where there used to be grass.’

The textbooks also, by their own account, invited students to “participate in the construction of an argument” (FUNDAEC, 2005b). Lesson 4 of “Environmental Issues,” entitled “Factors That Affect Air Pollution,” began by asking students to make a list of possible factors affecting air pollution, and then introduced four factors over the course of the lesson. A mix of questions and statements posed in the textbook helped students arrive at those factors in part through their own reflection. Questions included:

Are you aware of the ways in which emissions can be reduced in an automobile?

How would the level of pollution change if, in a microregion, [a] new type of engine [that emits half as much pollution as other cars] was installed in every single car?

Now imagine that... automakers built cars which ran exclusively on this new type of engine, but that many more cars were sold, tripling the number of cars in the microregion. What effect would this have on the overall air quality?

How would the level of air pollution change in a microregion if every car was installed with a device that reduced its emissions to a third of what they were before, the number of cars in the region doubled, and everyone started driving three times as many kilometers as he or she did previously?

Through these questions and a number of statements, students were pointed to factors of air pollution such as the amount of pollutants released by each car, the number of cars in a region, and the amount of driving people do. The experiences of the Kanini 2 group in studying early lessons of “Environmental Issues,” then, highlight three ways students are drawn upon as sources of knowledge, by calling them to: (1) use their own experiences to

make statements about reality, (2) analyze patterns in things they observed, and (3) use logic to participate in the construction of an argument. These means of student participation were reoccurring across textbooks and PSA groups.

In the training of tutors, expectations of students contributing on the basis of their own experiences and reasoning were impressed about tutors. In one instance, for example, Margaret, a veteran tutor sat with a small group of new tutors whose groups were going to begin the following week. To help the new tutors prepare for their visits to existing groups that afternoon, Margaret went through a lesson of “Ecosystems” as she would with her group of students, stopping periodically to add commentary for the new tutors, such as:

You stop after a long part and ask what they understand, because you know your students and some understand slowly, so you ask questions.

Most of them have their gardens at home so they will be able to tell you ways that they get water during the hot season.

When you [as a student] give an answer, no or yes, you just have to explain it. Most answers are right if you give a good explanation.

The lesson is making students be good observants of things... You can't see sitting at home, you have to go close and see. You can't wait for the neighbor to come, you have to go close.

With the second comment, Margaret reiterated to the new tutors that students already have relevant experiences from which they can make valid knowledge claims. In the fourth, she suggested that part of the aims of the learning process was to help students further refine that ability to know on the basis of their own observations and experiences.

Considering students an important source of knowledge stands in contrast to those frequently criticized approaches to learning in which knowledge is ascribed to those in

authority, such as teachers. Tutors, in their own descriptions of their work, made this distinction repeatedly. One tutor (12F) explained, for example:

A tutor is different from a teacher, a teacher will be standing in front, teaching the students what he learned; but for a tutor, he will be there facilitating discussion, just to help the students maybe where they are not clear.

Another (Tutor 8F) described:

When you are in class, for instance, you don't have to want to be superior and want to speak all the time, but you give chance to all the students to express themselves. Yeah, you are not superior because you are also gaining the same knowledge... Yeah it's different from other ways of teaching. You know when other organizations, or other groups are teaching in the community, they are teaching. But we are learning and teaching, it's quite different.

To this her friend and fellow tutor (7F) agreed, adding:

You are learning from those people [the students] and they are also learning from you, so you have to consider each and every point that they give.

According to these tutors then, part of their role as tutors, in the figured world of PSA, was not to position themselves as the primary source of knowledge in the classroom. Instead, they sought to have students see themselves as important sources of knowledge, by asking them each to take an active role in discussions and to seek assistance from one another, instead of only from the tutor.

Reoccurring in these interview comments, instructions of old tutors to new ones, and classroom interactions is the idea that students should draw upon their own experiences and reasoning in the learning process. In this way, students can be considered important sources of knowledge in the figured worlds of PSA. Their contributions to the classroom discussion on the basis of previous experience and personal reflection are valued elements of the activity that characterizes that space. Yet, as much as comments dur-

ing interviews or classroom discussions emphasize the role of students in their science learning, the notion of students as sources of knowledge needs to be teased apart a bit more. In contrast to learner-centered approaches (e.g. McCombs & Whisler, 1997), students were not directed to draw conclusions about reality solely on the basis of their own experiences. Much of the content of the texts introduces ideas from the natural sciences and helps students understand models and concepts that have been generated by scientists, rather than encouraging students to reach such conclusions on their own. Students, then, are one of several sources of knowledge valued in the figured world.

Multiple Sources of Knowledge

A second notion, then, related to the topic of sources of knowledge and prevalent in the figured world of PSA was the preference for consulting multiple sources of knowledge. Junior's practice of asking multiple students to comment on the same question, mentioned above, was common in PSA groups. When one student struggled to provide an answer when it was his or her turn, or when an answer was provided that was not quite correct, the refrain, 'Who can help their friend?' was commonly uttered by tutors.

The descriptions of participants about the nature of study in PSA also suggested a value on bringing together multiple perspectives. For example, one student (Mboo 2F) explained:

In this program, each person must share their ideas for us to know well. When we combine your experiences and mine then we can see a bigger picture. For example, you can share about the pollution you have seen, or what your family does with its trash. Maybe I know something about how that store manages its waste. Then together we will know something more about this topic.

In the textbooks, this orientation was modeled by stories in which several different characters combine their insights to form a more complete picture. For example, the “To the Tutor” preface of the unit “Planting Crops” explains:

The remaining lessons [after Lesson 1] consist of a dialogue on the subject of crop production that opens up between four characters, each of whom brings a different point of view to bear on the discussion. A young man, who wishes to help his grandmother improve production on her small family farm, is seeking the advice of others on how to proceed. His grandmother provides a perspective that is informed by the traditional knowledge system of the region. His friend, who is studying at a nearby university, brings the views of a specialized science of agriculture to the conversation, while his cousin, a participant in one of FUNDAEC’s programs, shares some of the innovative ideas she has learned in the course of her studies. In discussing the options before the young man, the group avoids falling into extremes... Instead they strive to take a balanced approach to change, one characterized by a healthy relationship between the cultural heritage of the local population and modern science. (FUNDAEC, 2005a, p. viii).

In the story running through this unit, then, four characters, envisioned as each bringing a different point of view into the discussion, explore together possibilities for raising productivity on a small family farm by understanding the factors that affect crop production. Such narratives serve as an example to students of what their discussions should look like, and are found in other units, such as “Transition to Agriculture,” and “Ecosystems.”

The textbooks also ask students to consider the diversity of sources they might turn to in their work. This was especially evident in the study of “Heath and Disease,” as seen in the following field note:

While I missed the study of Lesson 1 with the group, they used the first few minutes of today’s lesson to review what they had talked about. It seems there were one or two students who also missed. In the first lesson, they listed activities carried out in their community and thought about them in terms of ongoing processes. They then analyzed these processes in terms of certain criteria (placing them in order of most to least for

each): which processes seemed to need considerable change, which were urgent, and for which did the community itself seem to possess the resources to improve them. On this basis, they identified acts of service that they might undertake to help the community.

The second lesson, it appeared, was to build on the discussion of the first. At the instruction of the tutor, students took turn reading the paragraphs of the lesson. After every one or two paragraphs, the tutor asked the students to share with one another what they had understood. At one point, there was a long pause as no one offered to summarize the paragraph. The tutor asked someone to reread it... In the fifth and last paragraph of the lesson, students were given the following instructions: “For each of the acts of service you identified in the previous lesson describe, in the form of an outline, some of the knowledge you need to acquire. Include in your outline the proper sources of this knowledge.” The textbooks then contained give blank charts for students to fill out. The tutor directed the group to break into small groups of three to fill out the charts, saying that after half an hour they would come back together to generated completed charts altogether.

...The charts below capture the two charts that the large group was able to generate on the chalk board before they day’s session was over:

Act of service: Promoting a healthy environment	
Knowledge	Source
What kind of waste is produced in the community	Do a research to ask families in the community
How people dispose of solid waste	Do a research to ask families in the community
Ways of disposing of waste that harm the environment less	PSA books, Families, Environmental agency
Which materials are biodegradable and non-biodegradable	PSA books, Families
How to make a compost	“Planting Crops” [a PSA unit]

Act of service: Food production	
Knowledge	Source
How many people in the community have backyard gardens, what they grow, what methods they use	Do a research to ask members of the community
Kinds of fertilizers that are good to use in small gardens and don’t harm the environment	Ask members of the community, especially ones with good gardens, PSA books, do our own experiments

What kinds of plants grow well together	Families in the community, PSA books, library books, experienced farmers, agricultural extension officers
Pest control	Same as above
Weed control	Same as above

This activity, then, reiterated the idea the value of consulting multiple sources, asking students identify a number of sources of knowledge that might contribute to their knowledge in preparation for service.

Within the range of appropriate sources of knowledge that students consult, the figured world of PSA emphasized other members of the community as an important one.

This came up both in interviews and in classroom activities. One tutor (1M) described:

When we worked on our own garden, we used to find information from many places. Our [PSA] books had so much good information. Also we spoke to our neighbors and asked them how they do it. One man had an idea to use Boom [dish detergent] on the crops to keep pests away. So we tried that one for ourselves.

Text units about agriculture called for students to discuss farming practices with local farmers. Those about environmental health directed them to speak to small and large manufacturers and business owners about waste management. On the topic of family health and disease, they were instructed to speak to mothers and other community members to find out more about skin diseases and intestinal parasites, their prevalence, what is known about them, and how they are treated. In many of these instances, students were also able to share some of what they were learning with others. One graduate (Site 3F) described:

It was nice, because we were also learning something [and] we used to share with them. We were getting more, what can I say, we were getting more knowledge also from them. It's like we were just teaching each other. If we ask them questions, they answer and after answering, we learn from what they are answering.

A graduate (Kolwe 1M) considered learning from others in the community one of the things he appreciated most about the program:

EL: Was there something that you especially liked about the program?

B 1M: Yeah even the thing of having researches, learning a lot from people, and also where we could go in industries, so I was exposed to some knowledge that I never had before. So I had some interest of gaining that knowledge. And see what can help me with in the future, and see how I can also help serve in the community with that knowledge also.

While the next chapter will explore in greater depth the ways that knowledge from different sources, particularly modern science and local knowledge came together, of interest here is that the epistemological orientation woven into the practice of the PSA community was one where consulting multiple sources was valued. Tutors tended to seek the input of more than one student, even if the first produced a ‘right’ answer. The textbooks featured stories with characters who brought to bear ideas from different perspectives in a consultative manner. And they instructed students in numerous activities to do research and collect insights and experiences from other members of their communities.

Conclusions

In the personal epistemology literature, assigning to authorities such as teachers and scientists sole responsibility for knowledge and truth was considered a characteristic of an immature epistemological orientation. The developmental orientation to epistemology of those thinkers considered that as individuals matured in their beliefs about knowledge, they saw for themselves a more important role in determining truth and came

to understand ways that knowledge is generated by human activity. Such shifts are closely related to considerations of knowledge certainty, to be discussed in the next section.

In the Preparation for Social Action program, participants' actions and self-accounts tended to dismiss orientations to knowledge that relied exclusively on authorities as sources of knowledge. Such orientations they related to their experiences in school, and they mentioned these school experiences in contrast to practices within the program. In describing the impact of their study of science in PSA on them, part of what they conveyed was a change in how much they felt they knew, how they were able to use what they knew, and how capable they felt as sources of knowledge. The highest states of epistemological development in personal epistemology literature often connect to relativism and the denial of knowledge authorities altogether in favor of reliance on the self as a source of knowledge. Yet, the comments of participants, the content of the texts, and the interactions in the classroom do not seem to promote this orientation to sources of knowledge either. Certainly, science is given special authority, as other sections of this chapter and the next will explore further. While some tutors characterized their work as mere facilitators of discussion, other comments below will illustrate their concern how students' understanding aligns with knowledge sources, such as science. The excerpts of interview comments, field observations, and recorded classroom comments mentioned above convey some of the primary dimensions of how sources of knowledge seemed to be conceptualized in the practices of PSA. After a similar exploration around knowledge certainty in the next section, a review of documents created by FUNDAEC will allow for a look at some of the philosophical underpinnings that shaped the content of the program, which in turn has shaped the practice.

Knowledge Certainty: ‘PSA doesn’t come with answers’

One Monday morning at Inshindo’s main office, the group of five new tutors gathered around a table in the main hall. Nelson, a coordinator of the program, sat at the head of the table and provided tutors with a vision of their activities over the next two weeks. That week they would visit existing PSA groups and the following week they would start their own groups. While these tutors had been studying relevant materials over the last several weeks in preparation for their work, and had in that way received considerable orientation to the work of a tutor, Nelson took the opportunity to offer some last minute advice. Among his comments were the following:

Don’t just tell the answers. Ask the questions and they will find the answers. If you just tell the answers, students will not understand... We’re not supposed to feed the students. Don’t tell them the answers. There are no wrong answers in PSA.

With these words, Nelson passed along a sentiment reoccurring among PSA tutors and coordinators in their descriptions of their work. While the phrase ‘no wrong answers in PSA’ did not seem to be precisely true, in that all answers were not considered equally valid, the phrase does seem to convey the spirit of a particular orientation to knowledge certainty that characterizes the figured world. This orientation can be said to have multiple dimensions, two of which are explored here: that asking oneself questions and reflecting for oneself are highly valued, and that wrong answers are not belittled, but gently corrected or explored for their logic.

Asking Oneself Questions

An emphasis on ‘not telling the answers’ in the orientation tutors received seemed to derive from the desire that students think about things for themselves and ask them-

selves questions. This idea was reoccurring in the descriptions of students, tutors, graduates, and coordinators. For example, Kaweme, a coordinator of the program, described his early exposure to PSA content, drawing the following conclusions:

K: [When I first started at Inshindo] they gave me three books to see if it would attract my interest. So I was like, ‘why are you giving me three books? I am going to read these books in two days then be bored again.’ But I ended up passing through the books so slowly, they caught me. I was hooked, I loved them.

EL: What about the books caught your attention?

K: I found that they were interactive... One thing I have seen about PSA is it doesn’t come with answers. So we have to look for answers. So then, if someone reads from outside about a certain topic, then they are bringing in more knowledge, like it’s wide. Like I said, PSA brings situations, like mostly they are stories and the like. Some stories will just create this thing in the head, ‘but so why?’ So you ask why. ‘Why? Why did that happen there? Or how did that come about?’ So you want to find out more.

Kaweme’s characterization of the textbooks as leading one to ask oneself questions was reoccurring in the comments of participants. One student (Mboo 1F) described, for example:

I love these books because they are always making me to think, ‘why?’, ask myself questions that I wasn’t thinking of before.

As mentioned in the previous chapter, Alvin, a tutor in the program, found the science content in particular sparked a lot of questions in his own thinking:

In my case, I think it is so much important to learn the science part we are learning in PSA when it comes for you, for your own life, how you apply certain things. Do you just receive something, like a theory, without investigating about it, without learning more about it? ...I have to ask a lot of questions. So for me, for many things, I have like also developed such a mind of a scientist, to [think about] how these things are working this way. What other things maybe can I find out? Which can help into maybe working well? Or how did people came up with that conclusion? What methods did they use? How did they arrive at that conclusion for me to believe in it?

For Kaweme, this emphasis on questions, rather than answers, was quite different from his experience studying in college, where a stated value on personal investigation was contradicted by the reality of grading practices:

[In PSA] there is a lot of questions. They [the books] bring about situations that trigger some questions in your mind... So when the situation comes then the question comes in your mind, then you want to find out. Because at school it was rare that I would be in class and then come out with questions trying to find out something. Even though I was taught to say, 25% is from the trainer, and the other part is from research. I got most of the information from the trainer. Because if I go and research and write something the trainer didn't tell me, it was going to be, 'hey, you failed.' If the trainer is using a certain textbook then I also have to use that same textbook. If I use a different textbook, then there's some weird language, it becomes a different case. We even have recommended books. So when you go there, they give you a recommendation of books, so these are the only books you can study. Even though they will say recommended they are supposed to remove the 'recommended' and say these are the only books you can study.

According to the characterizations of these and other participants of the program, then, part of conceptions of knowledge certainty in the figured world of PSA was that there was not a direct presentation of answers, perhaps in the hopes of encouraging students to generate questions for themselves about the world around them.

A look at the textbooks, and the ways they were used in the classroom, seems to confirm such characterizations. The workbook-style textbooks of the program come with no answer key. Tutors help students navigate the questions posed by the texts on the basis of their own study of them at tutor trainings, rather than using a special teacher's version of the texts.

In the classroom, some of the questions posed in the textbook were not straightforward for students to answer, and discussion lingered. For example, in the study of

Lesson 2 of “Growth of a Plant,” about living and non-living things, the Kanini 2 group grappled with characteristics of living things, as seen in the following field note:

...Students took turns reading paragraphs. After a few paragraphs, the tutor asked the group to summarize what they understood... The rest of the lesson consisted of short paragraphs with many questions in them, followed by a few lines in which to write answers to the questions. At the tutor’s direction, the reader was to pause after every question in the reading to allow the group to answer the questions aloud before continuing. Part of the resulting conversation looked like this:

Emmanuel: (*reading*) “...One thing you immediately notice is that the animal moves while the rock does not. Can we say, then, that one of the characteristics of a living being is movement?”

Several students: (*after a pause*) Yes. Yeah.

Emmanuel: “Do all animals move?”

Several students: Yeah. (*pause*) Um, yes.

S1: Yeah, I can’t think of any that don’t.

Emmanuel: “Do plants move?”

Several students: No.

S2: Wait, yes I think they do. The tomato plant, for example, you use the wooden sticks, what are they called, for the plant to move up, so the tomatoes don’t grow on the ground.

S3: That’s not moving, that’s the way they grow. They grow in the direction there is space. I think--

S2: No I think that one is moving. Or also, if you plant growing next to a wall, the leaves are always pointing in the direction of the sun. They are moving in that direction...

(In a few more comments students assert that plants do not move. The reader then continues.)

Emmanuel: “If we throw a rock, it will move. What is the difference between this movement and the movement of an animal?”

S4: The animal causes its own movement but we are the ones who threw the rock. It couldn’t act alone.

Emmanuel: “When the wind blows, trees move. Is that because it is alive? Does the wind itself have life?”

Several students: No.

S2: I don’t know. Maybe there is something like the wind is alive. It is coming from somewhere and going to somewhere, by its own movement. It is maybe even like itself breathing.

S5: No I can't think the wind is alive. It hasn't parents, it doesn't grow or change.

(The conversation continues with a few more comments, mostly pointing at why the wind isn't alive. Emmanuel then continues reading, finishing the paragraph with instructions that they write down their conclusions about movement as a characteristic of life.)

...Later in the lesson, the group went through a checklist of words and had to decide which were living and non-living. First, they checked off the list on individually in their books, then discussed their answers together. On the list were words such as: yeast, a heart, a seed, a virus, an orange, a thought, and a river. At a majority of the twenty-two items of the list, particularly the first ones, the group took a long time going back and forth about whether or not it was living. Gradually, a pattern emerged around which they could agree: some things were not living things in themselves, but parts of a living thing, like a heart is part of a living organism's body and a rose is part of a living rose bush. This made it easier to go through most of the items of the list, though it was confusing when they reached the item "a cell."

About this lesson, one student of the group (Kanini 2 2M) described:

That was a lesson that made me think and question a lot. The idea of living things seems so obvious. Before I thought I could easily tell you which things are living and which are not. But I am seeing now that things are sometimes more complicated. Even a robot that is really smart can seem like a living thing.

Sometimes through discussion then, it is not just that consensus is built by bringing together different perspectives. Also, ideas are seen as more complex. Knowledge is not presented as straightforward and coming from an external source, but rather it necessitates careful reflection on the part of the learner.

Consideration for Wrong Answers

Also notable in the PSA classrooms were certain patterns of reactions to incorrect answers. For one, tutors often did not say very much when students responded to a question incorrectly. This is seen in the following excerpt from field notes:

After students read a section of the unit “Diversified High Efficiency Plots” aloud, Daniel, the tutor, tried to review the main ideas of this section by asking the question, ‘Why is it difficult to know when to irrigate?’ There was silence for a couple minutes. A majority of tutors returned their eyes to the page, rereading. A couple sharpened pencils or looked up at Daniel waiting for an answer. One person offered an answer, ‘we will not know when the rays of the sun will be strong.’ The answer drew from, and contradicted, a statement by one character in the story that, “the best time of day to irrigate is when the rays of the sun are not too strong.” Daniel made a gentle grunt and barely noticeable nod, and continued his gaze around the table, not criticizing the answer but seeking more. Another answer was put forth and got the same lukewarm response and non-verbal invitation for more contributions. A third person (Bwalya) stopped the flow of conversation, with the word ‘wait’ and stated that he did not really understand the question, restating the question, ‘why is it difficult to know when to irrigate?’ Daniel suggested that the difficulty people were having with the question might suggest that during the reading what was said went in one ear and out the other, he mimed the idea with a gesture. Someone stated that it is difficult to know when because it is affected by different factors. Daniel asked the group what those factors are and they came up with the following list: the type of soil, the climate, the stage of growth. ‘These are things they need to have in mind when determining which type of irrigation to use,’ he concludes. They continued on to the next section... [They began speaking about the environmental impact of different irrigation options.] Daniel asked the group about sprinkler technology, whether it is environmentally friendly or not. A couple students responded affirmatively at the same time, one saying that it is ‘very friendly’ to the environment. Daniel asked, ‘are you sure?’ One person said, ‘yes, if the land is flat.’ Another expressed doubt, ‘I think it might carry away the top soil.’ Bwalya reminded everyone of the sprinklers at Banani, where their trainings used to be held. These sprinklers move around in circles suggesting to Bwalya that they are covering a lot of land without damaging it or removing topsoil. Another added that only if you put the sprinkler on a hill will it carry topsoil. Students laughed and one said, ‘who would do that?’ Daniel transitioned them to drip irrigation, ‘is it environmentally friendly?’ ‘Yes,’ said one, ‘friendly but expensive.’ Daniel agreed, adding that if one doesn’t care for the equipment nicely it might damage the environment. They moved on to underground irrigation systems. One person (Bwalya) suggested that underground tubes, if not cared for properly, could rust and damage the soil. Daniel instructed him to reread the description, upon which he discovered that the pipes are made of clay. He changed his mind—they shouldn’t damage the environment.

In this example, the tutor said nothing in response to incorrect answers, offering only a slight nod and gentle grunt. He asked the question, ‘are you sure?’ to an answer that is indeed correct, and instructed another student to reread the text when his comment contradicts information presented there. According to tutors, such considerate responses to wrong answers were important for creating an environment in which students feel comfortable sharing ideas. Two tutors shared the following in an interview:

EL: How did you learn to be a good tutor?

Christine: There’s a document that we studied, and also I was looking at— Aaron was our tutor when we were in the [tutor] training—yeah, at how he was facilitating, yeah and those were just my examples. And I went to Caroline’s class in Mine, while she was facilitating there, and I also got some experience from there. And from a document that we studied, and even from other tutors. Yeah.

EL: What did you notice from Aaron, the way he facilitates?

Christine: Whether you give a wrong or a correct answer he will just wait patiently until you finish your answer. He will never tell you it’s wrong, like that. He would never condemn us. Yeah he would just be there listening, yeah being so patient, and calm. And he was not favoring anyone, he was taking us equally. That’s one thing I liked about it.

EL: What about you, Laura?

Laura: Mm, I learned how to be a good tutor looking at my role model who was Aaron, because he was the one who was tutoring us. Like she has said it, when a student gives a wrong answer, you don’t have to embarrass that person just there and then. But you just have to, you don’t have to show it, that this person is wrong, but you just have to put it, just say yeah it’s correct, but in the actual sense you know that it’s wrong. You don’t have to embarrass a person like that.

EL: So how does a person learn, if a person says something wrong, but you don’t say anything else, if you say ‘yeah, it’s correct’?

Christine: You accept their answer [Laura: Yeah accept their answer] then you explain. [Laura: Yeah] You explain the correct answer. You make them understand.

In other words, being a good tutor means to these tutors that one should not respond right away to correct a student who gives a wrong answer, but find a way to help them understand without embarrassing them. Not responding harshly to wrong answers is likely

connected, then, to creating an environment in which students feel comfortable contributing to discussions, even though this might mean making mistakes.

Another way to which potential wrong answers were responded in the classroom had to do with trying to understand the logic behind them. As mentioned above, veteran tutor Margaret described to tutors-in-training that the correctness of an answer often had to do with the explanation attached:

When you [as a student] give an answer, no or yes, you just have to explain it. Most answers are right if you give a good explanation.

Asking students to explain the logic of their answers was another reoccurring pattern on the part of tutors. It came up that same day in Margaret's PSA group, for example. Field notes describe:

Today the group studied a lesson in "Ecosystems" that told the story of a family learning to manage the ecosystem of their backyard garden. At one point, the family discovers caterpillars have been attacking their garden, and the lesson asked students for ways the family could protect their garden against the pests. In response to the question, Ellie brought up her own challenges with insects, mentioning a couple techniques she had tried that didn't work. Other students answered the question with the suggestion to use pesticides and to 'naturally' remove pests by hand. A few students gasped at the latter idea but the tutor emphasized that this was not for a large field but rather a small garden. Then another student, Jack, offered his suggestion, 'I think maybe they can use crop rotation.' The tutor asked Jack to explain his thinking. 'With crop rotation, I think that if certain insects are attracted to one crop, then maybe the next year you plant another crop, the insects won't come to it,' he responded. To this, Ellie asked to share her own example. 'One time I had crops and the insects were eating them. So the following year I planted another crop and the insects came back. They came back. So I think maybe that option cannot work,' she concluded. Then the tutor responded:

Well, maybe this crop rotation is not very useful for protecting against insects, but it is very useful for improving the soil. If we don't want the soil to be drained of all the same nutrients, we can be planting different crops in different seasons. So we thank [Jack] for reminding us all of this important technique.

In this case, then, Margaret, the tutor, took a wrong answer, and identified the logic behind it, and responded to the student with encouraging words. While it was made clear that the answer was incorrect, it was still identified to have value.

The tendency not to discount wrong answers straight away can be found in the textbooks as well. It is most clear in the unit, “The Heating and Cooling of Matter,” an 82-page book aimed at “fostering in students some of the capabilities that scientists draw upon to study and understand the world around them” (FUNDAEC, 2005b, p. viii). According to the introduction directed at tutors of the course, the book uses the example of thermodynamic processes—which are easily observed in everyday life and therefore more accessible to students—to illustrate scientists’ approach to investigating reality. The explicit comments of the introduction and main body of the text draw attention to the role of communities of scientists in generating scientific knowledge.

In the last lesson, students are told, among other things, that the accumulated knowledge of science “is not always right; it also contains beliefs handed down over the decades and centuries, many of which turn out to be inadequate or even misleading” (FUNDAEC, 2005b, p. 67). This assertion comes in the context of a discussion of the way theory informs observation, and the idea that scientific understanding of phenomena, such as heat, advances over time through the work of a community of scientists. The rest of the chapter, then, presents some previous theories regarding heat, including the idea of heat as an invisible ‘caloric fluid’ introduced in the 18th century and the theory of four primary elements (earth, water, air, and fire) from Ancient Greece.

Reference to outdated scientific theories was an element of the book that stood out to several students and graduates of the program; according to their own accounts, it

influenced thoughts they had about knowledge. For example, Alice, a graduate of the program made such a statement in recounting what stood out to her from that book:

EL: Are there some things about “The Heating and Cooling of Matter” you especially remember from your study?

Alice: *(after mentioning a few other parts of the book)* ...I think the book “Heating and Cooling” was very good. Even the part where scientists thought that heat is a fluid, where they were having those debates: “No, it’s not.” “It is.” Until when they discovered that heat was not a fluid.

EL: So what did you think about that part?

Alice: If you think critically, no wonder they called them great thinkers, they were thinking *deep*. What they said made a lot of sense, even though later other scientists found better theories. So, it makes me think we shouldn’t be relying only from those ideas that we already know, and be so attached, because they could turn out to be wrong later. So we should be willing to learn from others with an open mind. That’s when we can have a good community. When we are willing to learn from others. And we shouldn’t think that the knowledge that we have, we are so superior than others. No. And we should be willing to share with others. If they ask us, we should give them proper answers. We shouldn’t be selfish with our knowledge.

Another graduate (Kanini 2M) made similar comments about the same lesson:

When we were doing the last lesson, ‘Models and Theories,’ so we were able, because from there we talked about the theories that existed before the one we are using right now, so we even came to the point to say, ‘ah I think it is not just applying to this work of science, because I’m thinking that it is also helping us to say that we should not just stick to our own ideas that we are correct, so we should always be having that open mind and learning from the friends, then maybe we can even achieve greater levels of understanding.’ Yeah.

According to these former students, examining scientific theories that had since been disproven, and exploring their logic, encouraged them to consider that some of their own understanding might later be proven wrong. For that reason, they felt they should adopt an attitude of openness to others’ ideas.

Struggle

Knowledge certainty in PSA had a particular orientation. The emphasis was less on providing the right answer, and more on asking questions and thinking for oneself, exploring the logic of potential wrong answers. It was concerned with the development of understanding that came with such patterns of thinking.

At the same time, without such an emphasis on right answers, without easy access to correct pieces of information, tutors could sometimes struggle with their responsibility to help students progress through the books. One student mentioned:

I think my least favorite book was “Heating and Cooling.” I mean it was just okay. We had a hard time understanding. I don’t know, it was just confusing, and we couldn’t see how it was helping in our lives. Mainly I think even the tutor she was struggling. She could just keep telling us to read the book, but she couldn’t really answer our questions.

Beyond this, tutors could sometimes hide behind uncertainty when they were not well-prepared. While there were morning meetings twice a week in which tutors reviewed together the lessons they would be studying that week, if they were not prepared or did not understand well enough certain topics that their groups study, they would sometimes draw upon the idea of personal investigation to encourage everyone to research a question. Two tutors explained:

Natasha: There are times when you are facilitating, you won’t understand all the concepts, you find that the concept, maybe you are busy with some other things and you didn’t have time to go through the lesson you are going to facilitate. And then you go to class, the students ask you a question, and you don’t know how to explain it, I didn’t understand it. They will be, no, as a tutor, you have to lead us.

EL: So what do you do when that happens?

Natasha: As for me what I do, I tell them, you do a research, I’ll also do a research. We’ll investigate the answer we don’t know.

Lunza: I think from what [Natasha] has said I will say the hardest part is like telling a lie. Like what you’ve been teaching to them, the qualities that a person should have, we should not lie to anyone, you need to be

honest. So looking at the situation she has explained, like you were tied up somewhere and you never had chance—I would say we do have refreshers on Mondays and Tuesdays, maybe you missed a day like on Monday and then in the afternoon you are supposed to be in the class facilitating. So since you didn't go there you happen to find that the topic you are facilitating, maybe you didn't have time to go through it, you didn't even understand. Definitely then you are going to lie and say, 'okay guys, let's do this work or let's do this work tomorrow. We research and I go and research as well.' Because again you can't be open to them to say, 'you know, guys, I don't know.' They will feel, 'ah, what kind of a tutor is this? This guy is supposed to be here, like directing us or giving us these same ideas. We are learning from her and then she comes all the way from home just to tell us that I don't know.' So the hardest part is telling a lie to someone, that's the most hardest part.

According to these tutors, then, the orientation that did not emphasize right answers, but rather reflection and questioning on the part of students, could be used to cover up instances when they were not well-prepared as tutors. Though they saw for themselves a responsibility to help students understand better and help answer questions that might arise in conversation, if they were not able to do this in a given instance, potentially as the result of under-preparation, they relied upon knowledge uncertainty and the idea that everyone could simply research an idea further.

Conclusion

In the figured world of PSA, then, complementary to the stance on sources of knowledge as not being confined to authority, conceptions of knowledge are not confined to a simplistic duality of right and wrong answers. Sometimes two seemingly contradictory answers are both considered correct within a given context. Wrong answers are examined to better understand their logic. Such orientations to knowledge have particular implications for action, as will be explored in greater depth in the next section.

Conceptions of Knowledge and Science Agency

In an effort to understand better the link between conceptions of knowledge and the development of critical science agency, this section takes up six examples of critical science agency to see how the notions of knowledge prevalent in the classroom relate to examples of science agency outside of the classroom. Specifically, it asks the question, how do the conceptions of knowledge prevalent in PSA relate to the manifestations of agency mentioned in the previous chapter? In what ways might these orientations to knowledge shape agency? The idea is not to seek out a strictly causal relationship, but to offer an initial exploration into ties between epistemology and agency.

Agency as Applying Learning to Practice

Simon – expanding sources and techniques. Like many others, Simon had some experience helping on the family farm before he began in PSA, and he found that the things he studied helped expand his capacity for farming. He considered a combination of the knowledge he gained in his studies and a small amount of money he was able to raise to be crucial in allowing him to start a small farm for generating income. He described the change he saw in himself in the following way: “I think I can say my knowledge has grown wider in my study here.”

One way in which Simon’s knowledge had ‘grown wider’ was in terms of the number of sources he consulted. While he had learned a few basic techniques from his family growing up, Simon pointed to a number of new sources that impacted his farming work, including the textbooks, his colleagues in the program, and local farmers he met through these studies. He gave a few examples of things he learned:

S: When it comes to picking seeds, I [used to] just pick seeds from big plants, I could not consider other factors. But then after visiting other farmers in the microregion, I came to know that picking seeds, we should consider the period the seed matured, how long it took for that seed to be ready. So if you get seeds from a tomato that took long to be ready, meaning even your seeds will be taking long to be ready for harvest also. Yeah. So that is one I learned from farmers in the microregion...

EL: Do you want to share another thing you learned?

S: Another one is that groundnuts can also be planted together with the maize on the same piece of land. And of course we've been studying in PSA that a groundnut is a nitrogen-fixing plant. It grows well with other plants, but after visiting some farmers, after talking to some farmers, I could really see it, and how it was doing with maize on the same piece of land. So there are things that we know, but as long as we've never tried them, it's not easy to know it well. But when we read in the books, then interact with people who have ever done it, then our understanding of the theories becomes clear.

Specifically, in listing out sources he consulted before and after his participation in the program, Simon described going from an estimated 28 farming contacts he could list out, mainly family, to 36. Related to this change in number, was a particular perspective on the value of consulting others:

EL: Is there something you found especially helpful in your studies?

S: The thing that I learned is that if people are not interacting yet they are in the same area, there can be a situation whereby this farmer knows how to farm, or how to plant this particular crop very well, yet that other farmer does not know... So when farmers interact, they share ideas. This one it's like a mutual interaction. Both will benefit from their interaction. Because it's not possible that a person knows everything. You may know things that others do not know. You may not know things that others know. So when farmers interact, the sharing of knowledge makes them become good farmers. Yeah.

These comments about the importance of farmers sharing what they know with one another mirror the expectations and pattern of interaction in the PSA classroom. Students were expected to share each their ideas and experience in order to learn from one another, and help each other where they might have difficulties. Simon's expectations that this should be the case for farmers might be tied to the system of values and meaning that

characterize study within the program. It might also relate to the practice, as a part of studying the units “Planting Crops,” and “Diversified High-Efficiency Plots,” which called for students to repeatedly go and ask local farmers about their work. Whether it is derived from either, both, or neither of these sources, the orientation to knowledge-sharing Simon described seems to be built on the same epistemological premise—that knowledge is richer as multiple individuals pool their insights and experience to understand a single complex reality.

Another way Simon described his knowledge as having grown related to the content of what he knew. In the interview, he mentioned seven things one need to know in order to farm—land preparation methods, seed selection and storage, planting seasons for different types of plants, water and irrigation methods, pest controlling, weed controlling, and diversifications of crops (mixed-crop planting)—and then explained:

So most of these things, I knew them before I participated in PSA program, before I interacted with other farmers, but then the understanding was indirect. I could not understand the implication of all these methods. But after interacting with farmers in the microregion, after participating in the PSA program, I have come to have a wide range of knowledge concerning all these ways of doing things on the farm. Yeah. Meaning the application of scientific knowledge and the traditional knowledge that is already generated in my area makes one become a prosperous farmer.

Specifically, Simon considered his science study and interaction with farmers to (1) expose him to multiple ways of accomplishing a particular task, rather than the one or two options he knew previously, and (2) help him understand the purpose of techniques he was already employing. This is evident in the chart below, which has organized Simon’s comments into “before” and “after” categories that reflect his own description. When read row by row, left to right, the chart captures the entire flow of Simon’s commentary, without interruption (with a single ellipses in the top right box).

Table 6. How Simon's Science Agency Grew Through PSA

Before PSA	After PSA
<p>Before I participated in PSA, the only kind of land preparation method I knew was making beds. Yeah.</p>	<p>Then after participating in PSA, I came to know that it's not every crop that has to be planted on a raised bed, or it's not always that we plant crops on raised beds. But it depends on the kind of area, rainfall, and also the elevation...</p>
<p>When I was young, my parents could get seeds from big plants, usually and also they could keep it in airtight containers. But then the scientific meaning, or maybe the benefits of doing that was not very much clear, though I could practice it before participating in PSA.</p>	<p>And after I participated in PSA, I came to understand, like there were reasons behind doing it like that.</p>
<p>Then planting seasons for different types of crops. Mostly my understanding was like planting season was always raining season, in dry season you cannot have plants on the farm, yeah. Mostly people depend on the rains, so then I was thinking, like always, farming is always in rainy seasons.</p>	<p>Then later on, after participating in PSA, and also after having a chance to visit a number of farmers in the microregion, I came to understand that we have water in the rivers and lakes that we are supposed to be using even when there are no rains. So it's not only the rains that we should use for irrigation. We have a number of sources of water.</p>
<p>Also, the other point is on pest controlling. Before I participated in PSA, I did not know that we can do something about pests attacking our plants. So if I failed by that time, if I had crops, if the crops were attacked by pests, I had nothing to do with the pests. All the crops could be damaged by the pests.</p>	<p>But now, after participating in PSA, and also having a chance to ask a number of farmers concerning pests, and the method they use to control pests, I've come to understand that pests are controllable, either using organic ways, or using chemical methods to control the pests. Then also through PSA I learned like, both has advantages and disadvantages. Yeah, so the idea is just to see, or to choose, the best of the two, depending on circumstances.</p>
<p>Then weed controlling also, the only method I knew was removing the weeds using hands or hoes.</p>	<p>But now, after participating in PSA, I have come to understand that there are certain practices that we are using that would help to control weeds. But we did not just know that this is also helping in controlling weeds. But now in PSA I have come to know it, though we are practicing it, it was also helping controlling weeds. So now the understanding is high. I was doing it, intuitively. (EL: Like what kind of things?) Like if you have a field, then you plant</p>

	<p>things like squash, yeah, they help in controlling weeds. Though we were putting squash in the fields, but we were not putting it with the knowledge of controlling weeds. So now, I have come to know that the only method is not just removing with weeds using a hoe or with a hand.</p>
--	--

It is not possible to verify the extent to which each of the changes he mentioned actually took place; some memory bias is no doubt likely. Of interest here, though, is the direction in which Simon described growing: becoming aware of multiple options for a given technique and understanding the reason behind practices he was already engaged in. Both of these characteristics relate to conceptions of knowledge described above.

The move away from consideration of a single way things should be done—for example, that seeds should be planted in beds or that planting must always take place in rainy season—mirrors movement away from the dualism of right and wrong answers considered by Perry (1970) to be an earlier stage of epistemological development. Familiarity with only one technique occludes the possibility of choice and the existence of factors that determine which techniques are preferable in a given situation, in much the same way that values, beliefs, and other aspects of context are obscured in simplistic conceptions of knowledge. In speaking to farmers and studying elements of agricultural science, Simon came to see a choice of multiple techniques in his farming work. This was rooted in an approach that exposed him to multiple sources of knowledge on agriculture, as well as one that avoided casting human knowledge as unchanging, absolute truth.

That Simon came to understand the reason behind certain techniques he was already employing, for example mixing maize and squash in the same field or saving seeds in airtight containers, also relates to the conceptions of knowledge described above. Stu-

dents and tutors of the program described an emphasis on the process of thinking for oneself and trying to understand over possessing a correct answer. Better understanding of why particular techniques were employed reflected greater scientific understanding of the phenomenon and fit well within an approach that allowed space for exploring the reasoning behind many differing ideas.

Simon's experience captures elements reoccurring among the ten participants who shared starting gardens on the basis of what they learned in PSA. While most offered a more in-depth account of other sources of knowledge they drew upon in their agricultural work—parents, other family members, neighbors, friends with particular expertise, etc—and no one else identified their studies in PSA as profoundly affecting *all* of the things important to know about in gardening, nearly all described advancements in familiarity with multiple techniques and understanding the logic behind techniques as a result of PSA. The one exception was Hillary, introduced in the previous chapter, who mentioned very few sources of knowledge (only her parents, the PSA books, and the tutor) and described what she learned in terms of singular techniques that one is 'supposed to' use.

Mapalo – fitting multiple sources together. Mapalo had been a tutor of the PSA program since it was first introduced to Kabwe. His interest and experience in farming long predated his participation in the program. At the time of our interviews, Mapalo had recently harvested his first large for-profit crop—onions—and made a moderate profit selling the onions to friends, family, neighbors and coworkers. While much of his agricultural knowledge came from sources outside of his studies, he described the program as helping him to understand “how what these different guys are saying goes together, they are speaking with one voice even if their ideas are different.”

In contrast to Simon, Mapalo had the habit of consulting a number of sources on farming matters even prior to his study of PSA. As a child he learned from his parents in the small family garden, then as he got older, he spent school vacations in the family village, learning about agriculture by helping his uncles on the farm. After high school, he started to grow crops on the family land just outside of town and began seeking advice from many different sources. He purposefully befriended neighbors and acquaintances with agricultural expertise, such as a high school agriculture teacher, a friend of his brother who worked for a seed company, the owner of a shop selling agricultural tools, and an agricultural extension officer. He also spoke extensively with his two grandfathers on regular visits to them, and chatted with cousins and neighbors who were also interested in farming.

In studying and tutoring in PSA, Mapalo gained access to a few new resources from which he could also draw, including fellow tutors and students, a coordinator who had studied agriculture in college, PSA texts, books in Inshindo's library and farmers met in the practice activities of the group. Like Simon, he found the textbooks helpful for understanding the reasoning behind certain techniques he already used:

We used to go to the farms and weed. I didn't know that maybe the crops, the weeds will fight with the other crops for nutrients, water and sun. I didn't know. For me it was just a task. You do it because that's what you are supposed to do. But now that I'm engaged in this program, you will find that I know now why we are weeding. We know why we are planting two crops at a time, but long time ago we just didn't know why.

This he considered to shape his approach to agriculture. He continued:

So even on a higher level, I have a bit of understanding that everything I'm doing, there should be a reason. Why I am weeding, why I plant these two crops together, why I am managing pests in this way.

An understanding of the science behind practices helped Mapalo to navigate between the different techniques to which he was exposed in consulting multiple sources.

For example, he described:

Tomato used to give me a lot of problems. And I didn't know what to do... You would find that some neighbors are spraying [pesticide], other things. Then I just didn't know what to do, because they had access [and I couldn't afford it]. But now I have learned what the pests do, and how we can manage them, and how we can maybe avoid them in the first place... When you are confronted with a pest, first thing to do is maybe to see the possibility, if you can manage it without harming the environment. For example you can plant some plants that repel insects, like onion or tobacco, because we learned insects are very sensitive to smells. You can also use chili pepper spray or tobacco spray. These ones are also economical in cost. Also we learned about some other insects that naturally kill certain insects harmful to crops, like some wasps are good for that. But after that, if it's [still] giving you problems, you can maybe buy insecticide. This option is just okay because insecticides kill the pests, quite alright, but they also kill insects that are helpful to crops and they have chemicals that are bad for health. Crops with the pesticide, Logo, you cannot eat them right away. You have to wait for some days or it's poisonous. But it is a good option if the other ones aren't working, otherwise you may lose your whole crop.

Here Mapalo refers to a number of possible means of pest control, which he knew of from different sources. The use of insecticides was common practice, the idea of pepper and tobacco sprays he heard about from local farmers, and the ideas of planting onions and the existence of wasps that kill certain pests were from his PSA studies. Scientific explanations about the effects of the technique on the environment, on the crops themselves and those who eat them, as well as financial considerations, determined which techniques might be good to try first. Such complexity in thinking about techniques reflects an approach concerned with more than right and wrong techniques, right and wrong information.

In addition to making decisions about techniques on the basis of context and certain relevant scientific explanations, Mapalo's description of his experiences draws attention to another aspect of how he navigates different sources: he sees knowledge from different sources as potentially fitting together coherently. One way this stood out to him was in hearing about scientific explanations for traditional practices, which will be discussed in more depth in the next chapter. Further, when asked about how he navigates differences between sources, he emphasized an underlying harmony:

M: ... When I'm stuck I go to the library, after I read in the library, then I go to the friends, then I compare what I learned from the library and from the friends, then I can apply.

EL: So what do you do if they say different things, if the library book says one thing and your friend says something else?

M: Then I will say to my friend, but I read this, then this said this, but now you are saying this, so how can we harmonize the two knowledges? Then the other friend will say, no in the book they said that because it's like that, it's like that, it's like that. That's what they say in books, but originally this is. Like for example, I want to buy maybe for example these pesticides. In the book there is another name. They say, no that's the scientific name, but this is the brand name. It's the same chemical. So like for there, then you know, if they say this, then what they are talking about is this. So from him, it's more or less like experience and practical, so I read too, but I don't make them to conflict. No, I have to harmonize the two knowledges. That is what I have seen in PSA, these knowledges can fit together.

This is telling about his orientation to knowledge. The hypothetical situation that Mapalo uses to respond to my question is one in which two seemingly contradictory ideas actually refer to the same coherent reality when you dig deeper. Two differing names for a needed product actually refer to the same product, one being the scientific name and the other the brand name. Also telling in Mapalo's response is the way that he inquired about the differences, from the beginning wishing to "harmonize the two knowledges," in much the way that disparate converge in classroom discussion.

Mapalo's case illustrates, then, the development of agency in terms of navigating different sources of knowledge. In an approach that values drawing from differing sources of knowledge, students have to learn how to choose between different sources of knowledge and make sense about how they fit together. Five of the ten participants with gardens mentioned advancing in being able to do this.

Hillary – limited sources and techniques, counter-case. The examples of Simon and Mapalo demonstrate ways in which the conceptions of knowledge underlying their studies seem to have implications for how science is used outside of the classroom. In a learning environment in which students' own experiences and analysis are an important resource, where consulting multiple sources is considered to make for better insights, and where knowledge is not simple and certain but rather progressively advances, it would make sense that those applying knowledge to practice would find it important to: consult multiple sources, consider multiple techniques, weigh the merits of a particular technique on contextual circumstances, and reflect on how disparate ideas from multiple sources fit together. It is reasonable that science agency, as in the expanded capacity to use scientific content for individual and collective benefit, would entail, in part, growth in those directions. The examples of Simon and Mapalo reflect the accounts of nine of the ten participants who spoke in depth about their experiences gardening. All nine mention growing in the number of sources they consult, seven mention coming to consider multiple techniques, four describe trying to navigate how multiple sources fit together.

As mentioned above, the one who stands apart from this pattern is Hillary. As described in the previous chapter, Hillary started growing a small garden as a result of her agricultural studies in the program. Yet Hillary's description of her experience included

very few sources of knowledge and a simple consideration of techniques. For knowledge sources, she mentioned only her father, her tutor, and the PSA textbooks—authoritative sources. With regard to the neighbors and farmers that her group spoke to during the practices, she disregarded the possibility of learning from them:

H: When we were doing a research, that's when we did that, talking to people who they were making their gardens.

EL: Who did you talk to?

H: I can't remember. It was in PSA.

EL: Did you use any of their ideas?

H: No, instead we were teaching them our ideas. Because they were using fertilizers and chemicals. We were teaching them how to use manures and tobacco...

In terms of techniques, Hillary spoke in terms of replacing one (bad) technique with another (better) one:

Yes, for the gardening. Before we used to grow vegetables using chemical fertilizers, but this time I think I can't even waste my money to buy chemicals and fertilizers. It's better I just use organic fertilizers, that is even healthier to people than using chemicals.

All of her descriptions of suggested dualistic consideration of what one should and should not do, regardless of context:

EL: Did you know how to make beds before?

H: Yes.

EL: From where?

H: I learned it from my father. With my father we grew tomato and vegetables. Then you should plant one 5 cm from the other plant. This I learned from [my tutor], because when I was growing with my father, I never knew that this was 5 cm, I was just doing it however.

EL: So you just put the seeds wherever?

H: Yes. And watering is everyday in the morning and in the afternoon. Because if you just water once, plants can dry out.

EL: Where did you learn that?

H: From both my father and [my tutor]. Then if you see any danger sign to your plants, the [insect repellent] to use is tobacco. This one I learned from [my tutor], because before we were using chemicals. But this time because we learned how to grow vegetables using organic manure and or-

ganic chemicals, that's why we have come up with these tobacco to kill insects. I think that's all.

The orientation to knowledge underlying Hillary's approach stands in contrast to those of Simon, Mapalo, and others, and similarly contrasts the epistemology that characterizes the figured world of the program. As mentioned in the previous chapter, Hillary's example does suggest science agency. She is using the scientific content she learned to grow a garden and earn a small income. Yet, her growth in capacity stands as somewhat limited in comparison with others who are able to benefit from the insights of others who are not traditional authorities, and who are able to navigate different techniques according to particular circumstances. As a point of comparison, Hillary's case sheds greater light on the potential connection between conceptions of knowledge and science agency. Her experience seems to be similar the experiences several people mentioned of formal schooling—such as Kaweme's experiences with agriculture in college and Alvin's experiences studying electrical engineering—where they were taught specific techniques as correct, without much thought about why or potential alternatives.

Agency as Knowledge-Sharing

Elliot and Insofu 2 – sharing ideas in a manner that allows others to think for themselves. Elliot was the tutor of a group in Insofu. For years prior to his involvement in the program, Elliot had a strong desire to see the progress of his community and contribute something to it. When he first heard about the PSA program, he tried to join as a student. But the group had already been studying for several months, and he was told that it was too late to join. Yet, his enthusiasm led to him being invited to see about becoming a tutor of the program when it was decided to open a second group in Insofu.

When asked to describe a science-related activity carried out by the group, Elliot chose an early project to share with their community about the causes of malaria. While the group initially had a hard time getting neighbors to attend a meeting hosted by them, the local primary school eventually invited the group to share their presentation during a school meeting with parents. The matter of causes of malaria was an important one to discuss in Insofu because there were a number of misconceptions about the disease, which was quite prevalent in the region. Elliot explained:

Some believed malaria comes when somebody is soaked by rain, others feel like when you're eating pumpkin leaves, you know those pumpkin leaves called *chibwabwa*. Others think *chibwabwa* brings malaria. So after that [the real cause] is told to them, they say, 'ah, but why we have bitten by so many mosquitoes, why we don't get malaria? Not until somebody eats *chibwabwa* is when somebody gets malaria.' So we said, 'no, you can, there are different types of mosquitoes, these others they don't give any problem, but that mosquitoes called *Anopheles* mosquitoes, those are the ones that gives or that carries that malaria parasite.'

Misconceptions that malaria was cause by eating certain foods or getting soaked were common in the region, so the information the group shared about mosquito bites as the source of malaria was important. Of particular interest in Elliot's account of their efforts to share these ideas is the way in which he described the group preparing for that presentation:

EL: How did you prepare what to say?

Elliot: Yeah I think we had to put it in, I can say, in categories of questions. One, how the community knows about malaria? That was our first area of questions.

EL: So you asked them.

Elliot: To ask them, yes, how do they know about malaria? How much they know or how well they know about malaria? After they give us their views.

The emphasis here on asking questions mirrors the manner in which questions played an important role in classroom interactions. Though the topic of causes of malaria is itself

rather dualistic and straightforward—science has identified how malaria spreads and many common conceptions of its causes are simply wrong—the group chose to arrange its presentations around questions. Elliot explained his sense of the logic of the group:

EL: So why did you decide to ask questions first, instead of just tell them?
Elliot: Yeah we didn't want to be like genius, you know, that we know everything (*he laughs*), because it takes, it encourages conversation. Hear their views also. Because when we went there, we didn't go to go and teach them. But we went to hear their views, if they are also in line with our views. Then we tried to just go and bring those ideas together and see how we can now move together. Rather than to say, 'no, what you are saying is wrong, what I know is right, so follow what I am saying.' No, we just want to be patient and hear their views also.

Thus, according to Elliot, the group began their awareness-raising activity by asking questions of the community, in order to “[encourage] conversation” and “hear their views also.” In much the same way that tutors described not wanting to come across as superior and appearing to have all the answers, Elliot expressed a worry that on the part of the group that they not be considered “like genius, you know, that we know everything.” From there, the group shared the insights they gained from their studies about causes of malaria, in a manner that sought to “see how we can now move together.” Much like the tutors who were careful not to criticize the wrong answers of their students, Elliot's group sought to avoid conveying the sentiment that “no, what you are saying is wrong, what I know is right so follow what I am saying.” Towards this end, Elliot further describes a particular attention to language use, by continuing the above description with the following statement:

...And we say... not 'we have found such and such a thinking.' We say, 'it is said' because we didn't want to be genius people, and say, 'ah, we are genius and we give them everything.' No, we also respect their views. Yeah.

Such an orientation toward fostering an equal exchange of ideas, then, permeated Elliot's account of his group's approach to the project even to the level of the language employed. By using the phrase "it is said" instead of "we have found such and such a thing," the group sought to take attention off of themselves as the source of the new ideas. Instead, they presented ideas in a manner they hoped gave the listeners a chance to consider them for themselves. This, perhaps, related to patterns in the classroom where students were directed to draw upon their own experiences and analyze for themselves. It connected to an epistemological orientation in which authorities were not considered the sole sources of truth who must ensure others take it up, but rather personal reflection and investigation were important, at the same time that the knowledge generated by scientific communities was considered an invaluable resource.

Elliot's description of the Insofu 2 group's service activity about malaria connects to changes he described in himself more broadly as a result of participating in the figured world of PSA. He described:

I was a short-tempered man, I can say. And my view was that the way I see things, everyone should see them the way I'm seeing them. So I now think I've grown up in terms of that, and PSA's helping me, where it is emphasizing on conversations, initiating conversations, one to one, or maybe in a group. You hear also people's views, and you contribute, where it's possible to contribute. But make sure to hear what their views are. Because we are looking at a common goal, we need to achieve a common goal. But if you are just, if this one is sticking to his own ideas, then we can't achieve [our goal].

The approaches to interacting with the community in PSA activities, and orientations to interpersonal exchanges in general, that Elliot mentioned came up repeatedly in the community of others. Many similarly spoke of the importance of respecting the

knowledge of others, emphasizing the need for humility when addressing them. Alice, a graduate, described, for example:

If you go there, very humble, in a respective [respectful] way, you introduce yourself, where you are coming from, the program, what you want to do. Then you share with them. That also helps. And also, you should be willing to learn from them. And accept their ideas. That's when you can learn. Because if you go out there, you cannot be thinking as if, 'no, I'm the only one who knows about this information.' Because it's a two-way thing. You learn from them and they also learn from you. That's how you learn.

Here she emphasized two-directional learning. Illustrative of this approach, this graduate and others in her group mentioned ideas they appreciated learning from their project to start environmental clubs in high schools. They learned techniques to recycle plastic bags by melting them into floor wax and techniques to weave the plastic from corn meal bags into handbags, for example.

Mapalo and others mentioned taking care to introduce farming ideas that they were learning about in a way that allowed friends and family members to explore ideas for themselves. He explained:

Even my uncles from the village, they come consult, also I give them advice concerning what I read in PSA. Yeah like, 'no you don't have to be just concentrated on maize, you have to diversify.' Because them they are just concentrated on maize. So you would find that it's not healthy. So you advise them intuitively, you don't have to tell them that you are advising them, but you have to find a way of addressing them, even maybe you buy them seeds. So [you say,] 'when planting maize, you can even plant this squash, you can even plant watermelons.' So they will be forced to go and plant. And then they will find that they have food. Then next year for the harvest, then you can tell them, 'no, how was last year?' Then if it's good, then encourage them to continue. You say, 'no, I think you can continue growing more food.' So we keep sharing with them the knowledge that you have. 'You have to add on, diversify, you have to maintain the soil, you have to maintain the environment.' But we find a way of maintaining them or advising them, so that it doesn't sound like you are commanding them or like you are pushing them to start something that they don't like. So we share information.

Similarly, Simon shared his efforts to have his brother and others do some work in garden for a while, so that they could be exposed to some of the techniques he had learned in a manner that allowed them to test them for themselves.

Elijah – educating others, counter-case. The experiences of Elliot, Alice, Mapalo, and Simon were commonplace. Most of those who spoke of their interactions with the community described two-way exchanges in which both sides learned something new. They identified specific things that they learned from members of their community, often farming or waste management techniques, and described the ideas from their study of science in PSA that they tried to share with others. Several described changes in themselves in which they became more attentive to the needs of others in conversation and tried to converse in a manner that respected others' views and gave them an opportunity to explore new ideas. These reflected an epistemological stance in which both students and others with whom they interact were considered important sources of knowledge alongside books and other traditional authorities, and in which, personal reflection and thinking for oneself were highly valued.

Yet, it is worth noting that not everyone in the program described their knowledge-sharing efforts in terms of valuing the input of others or allowing them to think for themselves. Hillary, as mentioned in the previous section, did not identify conversations with neighbors and local farmers as helpful to her experience and instead described only sharing ideas with them. Similarly, a group of PSA students in Kanini cast themselves as the educators of others in their descriptions of their own efforts. In a small group interview, Elijah recounted:

One of the most exciting things was when we had malaria awareness, of which we had gone as far as [a neighboring rural community]... When we went there, most of the residents there, they never knew the most causes of malaria. Some were ignorant, they were thinking that when you eat sugar cane which is very cold, that's when you can get malaria. Even when you drink cold water, when it's too cold, you can get malaria. But we had a privilege to teach them that malaria only comes from a mosquito bite, which is the female one, of which they were surprised. We educated them how to prevent their homes, the times when these mosquitoes they are most active and how they should even cover their homes. And most vulnerable during to our study was pregnant women, so we also advised them, because we always interact with the clinic, we also said that we are going to introduce most of you to our local clinic, so that you can have the privilege to mosquito nets. Of which the response overwhelming, they appreciated us.

This description of the activity to raise awareness about malaria stands in stark contrast to Elliot's, though it is the same type of activity. Elijah uses phrases such as 'we had a privilege to teach them,' 'we educated them,' and 'we advised them' to describe the actions of his group, while speaking of members of the community as 'ignorant,' and 'vulnerable,' and saying that 'they appreciated us.' With such language he creates a hierarchy between them with relation to knowledge, implicitly identifying his group with authorities who possess knowledge and have to gift it to others who do not yet possess it. He even identifies that they 'always interact with the clinic,' other knowledge authorities. The knowledge he speaks of is simplistic and dualistic, though as mentioned earlier, the question of the causes of malaria does not lend itself to much nuance. Later Elijah describes 'educating the community' on how discard waste and how to grow backyard gardens. In this case, Elijah is describing his experience from a stance in which authorities are the primary sources of knowledge, knowledge is straightforward, and it is given by those who have it to those who do not. This stance was not as prevalent among participants' descriptions of their behavior and mostly came up only as students described their

previous expectations of the program and their experiences in schools and other settings. Elijah's comments seemed to fit within a prevalent model of development organizations in the region, in which knowledgeable outsiders trained local teams to extend that knowledge to the ignorant masses. It is possible that his decision to frame the group's experience in such terms was related to my presence as someone having the characteristics of a foreign development worker.

Adding another layer of complexity, another member of that group, Mr. Kalumba, described in the same interview the way his experience in the program had caused him to question people he previously held as knowledge authorities. He described:

Emily, this is not cracking a joke but a serious thing: I remember us when we had a study on manufacturing, where we thought that people who were educated, because that's where we find managers in companies, manager and so forth, with degrees, people—but we were amazed to discover that the so-called educated people, they are not. In the sense that they don't know actually what they are doing, or how they are harming the environment at large... Like one time I had an opportunity to discuss with the relationship with what we learned, I had a nice discussion with our manager and the personnel on what they think is the problem with our company where I work. Because it's a company which mostly uses chemicals and has the raw materials, it's a secondary manufacturing company [producing plastic bags]. So in most of our raw materials and imported materials, chemicals are already formed. So what I discovered is that they don't even provide like the protective shields to their workers, on which those workers, they tend to inhale those chemicals, but as we learned here, that such things are very hazard to somebody, especially workers, because them they are not there where they are, but people who are working there are the ones who are suffering to that... I took it upon myself to LEARN as we learned here, but to learn also what is happening in that space there. But those people seriously they will need to be educated. Because they are learned with other materials, but not with taking care of health for the workers. Which is very dangerous, because eventually we will all get wiped out because we are grassroots workers, we are not in the offices, we are in the industry where it's very dangerous...

In this statement, he noted that the managers at the factory where he works are typically considered educated, but he described himself as surprised to learn, in conversing with

them further after his study of “Environmental Issues,” that they were not taking into consideration the environmental damage and the damage to human health caused pollution at their factory. For this reason, he characterizes them as not actually educated, and states that “those people seriously they will need to be educated.” Of course, it is quite likely not the case that Mr. Kalumba never thought of the damage caused to worker health by factory pollution prior to his study of manufacturing waste management, although it is possible. While it is not clear what precise role his scientific studies played in thinking about the topic, of interest here is consideration of knowledge authorities. He recognized managers and people with degrees as “educated,” typically knowledge authorities. When this organization of things was broken by their demonstrated ignorance of crucial information, he did not replace it with a more collective orientation toward sources of knowledge, such as the one prevalent in his PSA studies. Instead, he suggested that those individuals needed to be educated. They were learned in some ways, but given their responsibilities, someone needed to educate them in other areas. The epistemological implications, then, still centered on rather dualistic conceptions of knowledge as true and non-true and acquired through the education of someone without knowledge by someone with it.

Such knowledge orientations have implications for agency as knowledge sharing distinct from the experiences of Elliot and those working on the basis of predominant conceptions of knowledge in PSA. Rather than bi-directional sharing, they imply linear patterns of sharing in which knowledge flows in one direction along a hierarchy. From this perspective, students seem to position themselves as knowing more than some and less than others, and interact with others accordingly. Such ‘others’ are often positioned

as mere recipients of knowledge. At the same time, the nature of knowledge implied seemed to be more simplistic and static, not open to interpretation. It equated to an established good that you can acquire.

The counter-case, then, reinforces what the case of Elliot and others highlights. Epistemological notions regarding the nature of knowledge and sources of knowledge shape the development of science agency as knowledge sharing. While one might share knowledge in a number of ways and for a variety of reasons, the PSA program seems to contribute to participants' developing the capacity to engage in knowledge sharing in a manner that values both the prior knowledge of others and their ability to reason for themselves. Beyond this, as previously noted, it connects them to a wider network of knowledge sources and helps them to navigate how insights from different sources might be applied.

Agency as Knowledge Generation

Jason – experimenting for one's self and learning in groups. Jason was a graduate of the PSA program who described "Planting Crops" as his favorite text. While he had a little experience helping with the family garden before he started in his studies, the garden project that emerged from studying "Planting Crops" was one that stayed with him. In the study of that unit, his PSA group in Kolwe planted their own backyard garden on the land of one of the students. They also were given seedlings to each plant their own gardens at home. In that way, the group learned through collaboration on the group garden and by sharing their experiences with their personal gardens. Jason explained:

We started a backyard garden for the group and we also had like, we shared the seedlings, I had even a backyard garden at my place, where I

could learn from home and also from the group. So we tried to sustain the same projects by so doing, like coming together as a group where you have your own backyard garden, you could even invite your friends to come and see it and maybe try to help in one way or another. So with that I became so much interested in the program.

In this case, then, students built capacity to garden in a manner that centered on generating firsthand experience and collectively sharing knowledge. Reflecting conceptions of sources of knowledge described above, students themselves were to be important sources of knowledge as they generated insights from experience. In pooling their collective experience, they drew from multiple sources and compared experiences.

Students in the Kolwe group compared what they saw in their textbooks to what they saw in their gardens. Jason described:

We could sometimes maybe get some vegetables, and then maybe have them in the meeting, those that we see they are having some defects. So we could have them and then try to look at those problems, and then we look in the book and consult as a group on what we had learned. If we failed, then we invited [the projects coordinator], then with [the projects coordinator] and [the program coordinator] there, we could ask to say what could be the reason of this and that? [The projects coordinator] he is the one that told us to say, when you're having maybe a problem with this kind, then the reason is that. Yeah. So we tried out ideas he suggested.

Students' knowledge about gardening was strengthened by testing out what they were learning in practice, following the instructions of the book and comparing what happened with the images and descriptions found there. Further, they generated insights about gardening by conducting small experiments. In one case, they had heard from a neighbor that soapy water from laundry detergent could be an effective means of pest control, so they tried it out on half of their garden and found it did indeed work. In another case, they decided to see what happened when growing a garden in rainy season.

J: The first garden that we had did well, of which it gave us so much courage to even start another one. Yeah. Of which we started another one,

even we had to start, we even thought of doing another project or backyard garden during the rainy season to see how the crops can do during the rainy season. Always we were told that gardens cannot grow in rainy season, so we wanted to see if it's true. So we made it also in rainy season.

EL: So what did you discover when you made the one in the rainy season?

J: In the rainy season? Only that to some extent there were like some insects that attacked them. Of which we thought it was due to the rainy seasons, they could like come and make holes in the leaves. You find that the leaves have got many holes... at the beginning I think the crops were just well, but after just some time, yeah that's when we started having that [the holes]... So we had to be looking at the garden, taking a closer look at the crops, seeing where, when we see one having the difficulties, the defects, we would remove it so that it shouldn't go to these other crops. That way we could keep our garden in rainy season. The neighbors were so impressed, to say, 'ah, but we've never seen this in the rainy season because of the insects that they attack most of the crops like the vegetables during the rainy season, but how have you managed, you guys?'

Through such small experiments, rooted in a desire to understand why or learn what worked, the students expressed an agency rooted in the conceptions of knowledge described above. They became sources of knowledge generating their own insights and they recognized that knowledge as potentially complex.

Beyond sharing ideas with one another and generating insights through their own experience, the students shared the knowledge they were gaining with others in the community. Jason mentioned:

Also we could even like receive visitors from the community who came just to look at the garden, maybe to consult about how we are going about it.

As part of the project, the group visited a number of nearby households, first to research the prevalence of backyard gardens in the community, then to share their own experiences with those who expressed an interest in starting gardens for themselves.

J: After we learned, we engaged about, first we started with five households which were engaged in the project. We shared the seedlings with them, and then we could go and help them with the necessary works for starting the same garden until we saw their crops grow.

EL: In what ways did you help them?

J: Like preparing the beds, yeah, even when it was time for weeding we could go there, we weed with them, and also just watering, we could go and also them we taught them how we were doing it ourselves. And we showed them the methods that we were using, the pest controls that we were using to say, even the fertilizer that we were using, we were using just organic manure. Yeah, we didn't want to use fertilizer because at that time we were learning about organic manure, the use of organic manure and organic pesticides. So those are the things that we were using, so we like taught them about the same, and then we shared seedlings with them. Those that said 'no, you can come and help us with this,' we went there, yeah, and they could come to our garden, have a look at the garden, how our crops are doing, and then also we could visit them in their places so that we could see their garden.

The students, then, were forging something of a learning community that extended to include their neighbors. From Jason's account, the students began by studying the text and trying to put what they were learning about gardening into practice in their homes at the same time that they established a demonstration plot together. They compared their experiences from home with the demonstration plot and the ideas of the textbooks. Later, they began visiting neighbors to see who else had backyard gardens. For those who didn't but wished to, they shared seedlings with them and started conversations based on their own experiences. They told of techniques they themselves were using and invited the neighbors to see what they were doing firsthand. From the experiences of neighbors, they could also glean other insights. A network of people was generating knowledge about agriculture in the region—how best to care for certain types of crops given weather, soil conditions, and insect patterns in the region—through firsthand experience of growing gardens, sharing ideas with one another, and drawing from books and other credible sources. Some were experimenting in response on the basis of questions that intrigued them, such as whether gardens can grow during rainy season.

The tapestry of applying learning to practice, knowledge sharing, and generating new knowledge found in the experience of the Kolwe PSA group was rooted in the conceptions of knowledge that characterized the PSA program as a whole. It depended on the notion that students and those with whom they collaborated could be key sources of knowledge, able to reason on the basis of experience, navigate different possibilities, and ultimately generate knowledge through action and reflection. Such widespread involvement in the act of generating knowledge required abandonment of conceptions of knowledge as the property only of designated authorities, and of simplistic clear-cut right and wrong answers. A better understanding of good gardening techniques and approaches would sometimes be messy and unclear. Sometimes competing techniques would work equally well, or a proven technique might for some unexplainable reason not yield the expected results. This was the nature of farming.

At the same time that the aforementioned epistemological orientations made possible this web of knowledge-generation, the experience of participating in it further reinforced those same conceptions of knowledge. For Jason, it was an important part of his experience:

EL: What did you learn from your own garden at your house?

J: At my house? What I learned was maybe some of these challenges, you can't do without a consultation with others and you cannot sustain the garden with the knowledge of your own alone, unless you like consult with others who are also doing the same gardening. So that maybe after consultation you can learn one or two things and you can find a better way of doing it...

Sharing experiences with one another was, for him, key to better farming practice.

In this case, given the lower prevalence of agency as knowledge generation, no counter cases emerged in the data. This was also likely due to the nature of the topic. It

would be unlikely to identify instances of agency as knowledge-generation, in which knowledge is considered the sole property of authorities.

Knowledge in the Conceptual Framework of the PSA Program

The above sections explore what conceptions of knowledge looked like in the study and practice activities of the PSA groups and what some of the implications of these were for participants' agency. Underlying these manifestations in action of the dynamics of the program were core principles and philosophical orientations identified and articulated by FUNDAEC during the years in which the program took shape. It is timely now to explore some of these. Doing so helps to highlight the fact that the characteristics of the community of practice identified above, what knowledge certainty and sources of knowledge looked like in practice, were not simply cultural byproducts of the rhythm of a particular community. Rather, they resulted from the purposeful reasoning and reading of reality of a group of educators. In other words, they reflect particular choices.

As mentioned in the first chapter, the PSA program grew out of the experiences of a group of scientists in the Norte de Cauca region in Colombia. Disillusioned with certain patterns of thought and action in other development efforts in which they had participated, they began their collaboration by creating a shared vision for themselves of certain fundamental conceptions. In a publication by the Centro Latinoamericano de Tecnología y Educación Rural (Celater, Latin American Center for Technology and Rural Education), a few described:

It is customary to think of the creation of an institution in terms of exact definitions of objectives and goals, of the [organization charts], procedures, and operative systems. For the founders of FUNDAEC, all these organizational arrangements would have to evolve in action and did not

need to be formulated according to the day's fashionable theories of organizational development. Simply, as a first step in setting up an institution, they embarked on a long process of consultation and deliberation that would allow them to reach a minimum degree of unity of thought on basic principles; they tried to outline the beginnings of a conceptual framework that would then evolve as they entered their search for alternative paths of development with the people of the region they had chosen to serve. The following are some of the results of these deliberations:

- The populations with which FUNDAEC would interact would not be perceived according to the visions common in the development literature and among projects of social action. Defining the poor as masses of undernourished people, overwhelmed by problems and needs—housing, employment, sanitation, education—places them in the minds of everyone, either as obstacles to development, or as elements of a political force that can be manipulated in the name of justice, well-being, or progress. It would be much more accurate and constructive for FUNDAEC to consider the participants of its programs as irreplaceable resources in a self-sustaining process of change. The challenge would be to find paths of action that would help the population translate this potential into reality and create possibilities for viable plans of development.
- Linked to this vision of the people as resources for social change is the strong conviction that every human being possesses great potentialities that an appropriate educational process can help develop and channel towards service to the community and to society at large. It was this conviction that led the group to begin its projects with the design of an educational program for the integral intellectual, spiritual, and social development of rural youth, who in turn constituted resources for the subsequent programs of research and action.
- ...
- Having decided that development should not be the process of imitation of the so-called “developed countries,” it was logical to reach the conclusion that one was embarking on a search down an untrodden path. In this sense, then, the task of FUNDAEC would be more that of a scientific search than of the implementation of a blueprint with predetermined goals and objectives. Naturally, as answers to specific problems were found, certain well-organized plans of action would have to be implemented, but the element of search and learning would always have to be present to some degree even in a straightforward plan of action, if the Rural University was to participate in its implementation.

(Arbab, Correa, & de Valcarcel, 1988)

These fundamental conceptions, along with a few others not listed here, shaped the processes pursued by FUNDAEC thereafter. It is clear to see their impact on the epistemological stance of the Preparation for Social Action program. With a vision of participants in their programs, not as bundles of needs, but as resources in an uncharted process of social change whose potential is released through education, it makes sense that students would be taken seriously as knowers—both with regard to their knowledge and experience prior to the program and in their ability to reason through ideas and apply knowledge. That the path of development is itself unclear perhaps informs the knowledge uncertainty that participants described; there is no blueprint, all the participants of this process of change have to forge the path as they walk it.

Complementary to the above comments, those at FUNDAEC have articulated perspectives of the organization specifically related to knowledge in greater depth in other books and documents. In a graduate level textbook articulating elements of the conceptual framework shaping all of FUNDAEC's educational programs, for example, one chapter drew from the work of physicist David Bohm (1980) to critically examine the limitations of certain tendencies in scientific thinking. Below are a few excerpts from the text:

In his exploration of the relationship between thinking about reality and reality itself, Bohm finds a profound connection between the fragmentation of the human mind and the fragmentation of society as it is today...

Fragmentation is continually being brought about by the almost universal habit of taking the content of our thought for a 'description of the world as it is'...

The Newtonian form of insight worked very well for several centuries but ultimately (like the ancient Greek insights that came before) it led to unclear results when extended into new domains. In these new domains, new forms of in-

sight were developed (the theory of relativity and the quantum theory). These gave a radically different picture of the world from that of Newton... If we supposed that theories gave true knowledge, corresponding to 'reality as it is', then we would have to conclude that Newtonian theory was true until around 1900, after which it suddenly became false, while relativity and quantum theory suddenly became truth. Such an absurd conclusion does not rise, however, if we say that all theories are insights, which are neither true nor false but, rather, clear in certain domains and unclear when extended beyond these domains...

In the above discussion, Bohm uses the evolution of certain theories in physics to demonstrate the meaning and implications of the statement that a theory is primarily a form of insight. The understanding that theory is a series of insights into reality, and not absolute knowledge of how things are, constitutes an important element of our conceptual framework...

Thus far, we have examined several concepts that are essential to our methodological perspective. We have become aware of the tendency of most methods and ways of thinking to fragment reality and have seen how such a tendency is related to the belief that theories are descriptions of reality as it is. This has reaffirmed our view of science, already present in many other units of FUNDAEC, that the scientific endeavor is a process of making models and theories for specific ranges of phenomena, the models themselves never being a replica of reality. Furthermore, there is ample evidence in the world that the models and theories we carry in our mind, whether elaborate or rudimentary, influence the way we observe things, what we see and what we accept as indisputable facts. This does not mean that we deny the existence of objective reality. We do not belong to those schools of thought that consider reality itself a product of human thinking. It is just that we distinguish between objective reality that is one interconnected whole, and our own models of reality that are necessarily about fragments of it.

(FUNDAEC, 1999, p. 98-104)

Here then we find other fundamental conceptions that shape the epistemology in action of the PSA program. Developers of the program held to the notion of an external reality but considered it too complex to fully know or capture in scientific theories. Instead, communities of scientists forge theories through dialogue that are characterized by a range of validity. In the study and action of the PSA in Kabwe, it would seem, students

began forming similar dialogical communities, investigating reality and thinking for themselves, rather than simply taking in information, and sharing ideas with one another to reach deeper levels of understanding.

Identifying some of the philosophical positions underpinning the PSA program helps to orient the epistemology in action captured above. Yet, the experiences of participants captured above make clear that, although there were mechanisms by which these epistemological views were communicated to participants and encouraged among groups, there were a range of ways in which students and tutors engaged these ideas. Not all drew upon them in using what they were learning for personal and collective development, and some hid behind these same conceptions to avoid drawing attention to what they felt were shortcomings in their own participation in the community of practice. Attention to deeper questions about human nature, our ability to know reality, and other issues, have important implications for shaping the figured worlds of educational practice, and how what is learned is used. But they do not imply simplistic enactment of the assessments and positions of others; they become part of the dialogue of a community of practice.

Discussion

At a simple level, capacity to act for community development is enhanced through the development of particular skills. If one learns to make fertilizer from chicken manure or separate biodegradable waste from non-biodegradable waste—in other words, if one learns to farm in a way that produces higher yield for lower cost or if one develops habits that have a more positive environmental impact—capacity to act has been expand-

ed in a manner that can have beneficial individual and collective effects. When focused solely on this perspective, it might seem that skill development should be a primary driver of development and social change. Certainly, this is not an uncommon perspective in the field of international development. But sociocultural theory draws attention to the ways that the elements of culture implied by a practice affect the learning process and its outcomes. The case of PSA groups in Zambia and the ways that they enact meaning around notions of knowledge and draw upon those notions in their agency offers an opportunity to examine some of the intricacies of how this occurs. In doing so, the case contributes both to discussions of critical science agency and of epistemology in science education.

With regard to the role of epistemology in science education, this look at the experiences of PSA students takes up the question of the relationship between epistemology and the use of science outside the classroom. As mentioned above, most of those focused on personal epistemology were concerned with creating a developmental model that captured how young people come to arrive at mature orientations to knowledge over the course of their schooling (Belenky, Clinchy, Goldberger, and Tarule, 1986; King & Kitchener, 1994; Perry, 1970; Schommer, 1990). Schommer (1990) examined how students' epistemological beliefs shaped their learning practice in the classroom. This study looks one step further at how epistemological beliefs shape actions taken on the basis of what they have learned. Though it does not seek correlation in a statistical sense, in the way that Schommer did, the qualitative look here at how students framed their practice suggests a few manners in which epistemology gives form to students' use of what they have learned. For example, believing that every individual should be an active inquirer of real-

ity, one group of students carried out a project to raise awareness on the causes of malaria in a manner that asked listeners about their own thoughts about the matter, then presented new facts with wording that detached ideas from people and encouraged further reflection.

Furthermore, while Lidar, Lundqvist, and Ostman (2006) identified teachers' contributions to shaping the epistemological orientations of a classroom community through "epistemological moves" that indicated to students when they were on the right track with their experiments and when they should be taking different actions or asking distinct questions, the above description of the community of practice of the Kabwe PSA groups highlight a different sort of epistemological moves. Rather than indications of the teacher that lead students toward right answers or rights ways of conducting an experiment, the ethnographic account of learning in PSA shared here identifies ways in which the tutors, coordinators and texts of the program oriented students and tutors towards particular values and orientations to how knowledge should be conceived. For example, tutors were repeatedly told that there are no wrong answers, and not to feed answers to students, in order to emphasize a value around personal reflection and inquiry. Along the same lines, tutors encouraged multiple answers be given to a question, asking, 'What else?' whether or not the first answer was correct. Textbooks were filled with questions in the middle of lecture paragraphs that called upon students to participate in constructing major arguments of the lesson. And they directed students to ask questions of friends, family, and neighbors, thereby signaling members of the community as valuable sources of knowledge. Each of these should be considered an epistemological move that shaped the figured world of classroom learning in PSA. In utilizing the notion of epistemological

moves in this way, researchers can pay attention to the underlying values and beliefs about knowledge that shape a particular classroom community. They would note, for example, that in Lidar, Lundqvist, and Ostman's study, the actions of teachers were actually calling upon students to engage in a sort of inquiry that seemed to reinforce teachers and other authorities as primary sources of knowledge and cast students as mere imitators of these authorities.

The epistemological moves of the coordinators, tutors, and textbooks in the PSA program, along with the epistemological orientations they reinforced, help to answer the question of how to create empowering science classroom environments. Most of the studies of critical science agency prevalent in the literature rely upon the researchers themselves, or a small number of teachers with whom they are working closely, to forge environments that foster agency—the researchers or highly skilled teachers bear responsibility for creating activities that allow for student voice and the inclusion of outside knowledge, responding to student initiative and encouraging pursuit of opportunities for next steps. And success depends largely upon their ability to do this. In this way science agency becomes largely a product of the agency and initiative of select educators rather than a characteristic of an environment or social structure. Yet, in the case of the PSA groups of Kabwe, neither tutors nor coordinators (most of whom were former tutors) were highly trained educators. They were high school graduates drawn from the same population as the students themselves. Rather than specialized training, they became involved in a community of practice, with particular values, meanings, and norms, that oriented all participants in collective inquiry, seeking to draw knowledge from multiple sources. Involvement in the community was not uniform, and neither was engagement

with the values and meaning that characterized it. But instead of being shaped by the decisions of one or two participants, the environment and possibilities for empowerment were defined by the textbooks and a particular pattern of behavior and meaning that was passed from older participants to newcomers. This is an important distinction for discussions of critical science agency, especially in the context of community development. Previous orientations to science agency would seem to suggest the need for heavy emphasis on teacher-training. In PSA, textbooks played a key role in shaping classroom ethos, and rather than specialized teacher-training, tutors were educated in the community of practice first as students themselves in two-week long trainings in which they studied the same content according to the same methodology as students. In other words, tutors were at one point newcomers to the community of practice, who were helped to become full participants who then turned around and assisted new newcomers in their students. This consideration of environment and the norms of a community of practice, then, is one potential contribution of this chapter to discussions of critical science agency. It constitutes another way of undermining some of the individualistic assumptions of the construct, this time by limiting the importance of the teacher-protagonist.

Another contribution of the examples of this chapter to critical science agency has to do with the question of how critical science agency is developed. Discussions of agency through science learning have in most cases grown out of studies on identity, as seen in the introduction to this chapter. Such emphasis on identity, while important, has focused on learning effectiveness and constructed the outcomes of science learning in terms of identification with science and considering science-related careers. The exploration of this chapter has highlighted various aspects of how conceptions of knowledge are enacted

in the figured world of PSA—through identity, relationships, language, values and beliefs, tools and patterns of action. Both students and tutors take on roles of inquirers who draw from their own experiences and their interactions with one another, with the texts, and with the community in their practice and decision-making. This is shaped by a sense of purpose in contributing to the progress of the community, as captured in the moniker, “promoters of community well-being.” An ethos of ‘sharing knowledge’ casts relationships among the students and tutors as one of mutual support, though several tutors mentioned that this was something the group only developed over time. The student-tutor relationship was cast, in contrast to the student-teacher relationship, as one in which both are learning and neither has exclusive access to knowledge and truth. Certain patterns of language—including phrases such as ‘no wrong answers’ and ‘what else?’—communicated a pattern of action in which the input of many, and insights from different perspectives, were valued over a single right answer. Workbook-style textbooks, with no answer key for teachers, reinforced values of exploration and consensus building through consultation, action, and reflection, over the rote adoption and implementation of right answers.

Underlying any given educational approach are fundamental conceptions—about the value of knowledge and students’ motivations for learning, about the opportunities available to the learner upon completion of studies, about the possibility of social change and the means by which it might occur, about what can be considered noble or even reasonable aims for human life, about the capacity of the human being to know, about the extent to which knowledge changes or remains static, and about the relationship of human knowledge to a reality external to the human mind, among others. Such conceptions

are woven into all educational settings in ways that may be explicit, implicit, and even contradictory. They may be explicitly identified in advance by the creators of educational programs or may be embedded implicitly in the practices of a learning environment, unintentionally drawn from the norms of the culture in which the program took shape. In any case, the exploration of this chapter suggests that such fundamental conceptions have important implications for how experiences within the classroom shape agency, particularly the use of science outside of the classroom.

The implication of this, for the simple model identified in the previous chapter, is a more complex configuration of how science learning contributes to community development. While it is still true that learning a particular science content leads to greater capacity to act in ways that contribute to development, the content itself—the information, skills, and concepts—is not the only important element affecting agency. The learning process is constituted by particular values, meanings, roles, and relationships that shape the direction of agency. A few examples of specific cases illustrate this point.

Elliot and Insofu 2

In the case of Elliot and the Insofu 2 group, what students learned about malaria enhanced their capacity to converse with others about the causes of malaria. Ultimately this made a contribution, albeit small, to greater awareness of causes of malaria and practices that protect against malaria in the community. Complementary to the potential implications for malaria prevention, the approach of the PSA group—in asking questions, inquiring about community members' understanding of malaria, and posing their own

knowledge in a manner that invites their reflection—contributed toward a culture where community members reason for themselves and share knowledge with one another.

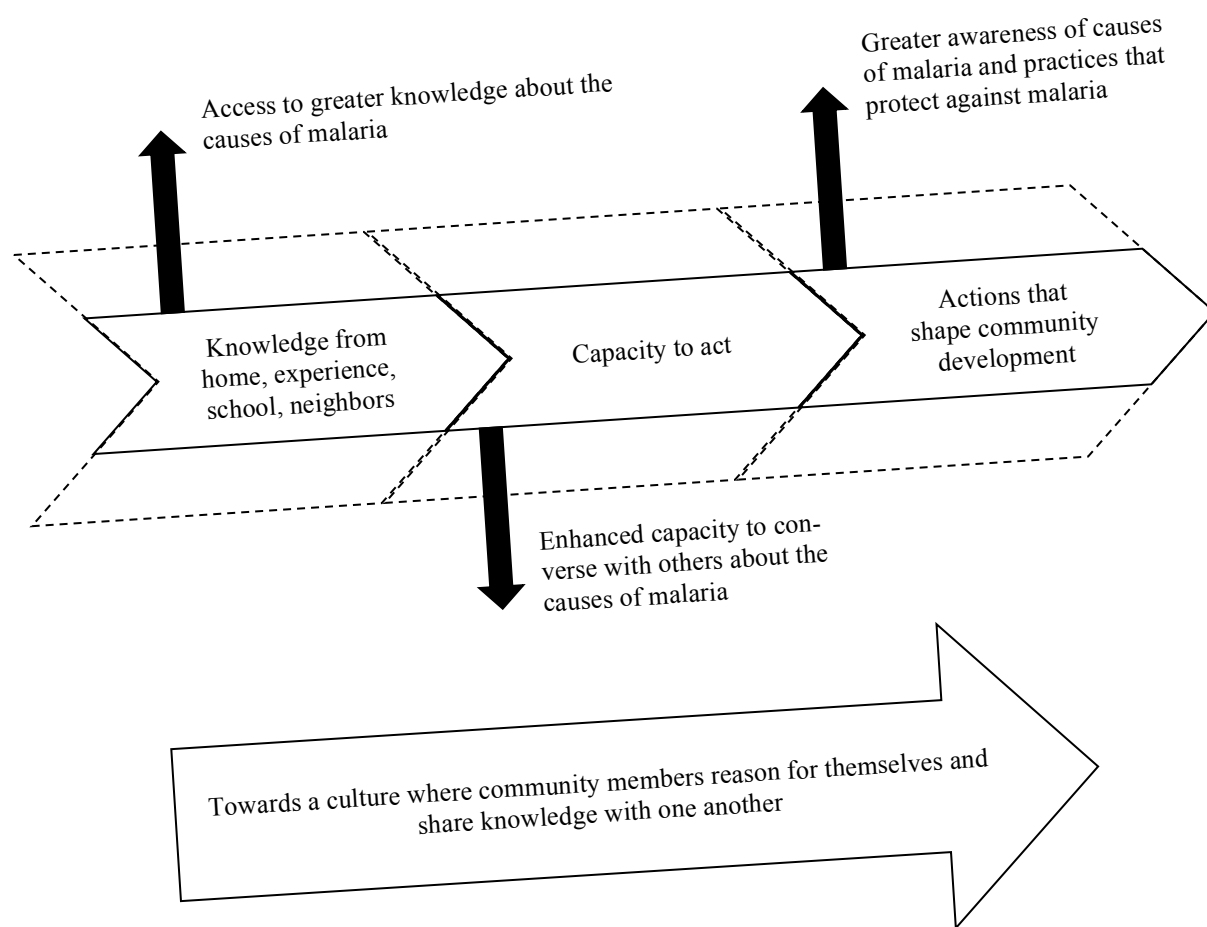


Figure 6. Model of Elliot and Insofu 2’s Use of Science Learning For Community Development

Jason and Kolwe 1

For Jason and his PSA group, learning about agriculture built capacity to both farm and engage in dialogue with others about farming. This contributed in a small way to the spread of environmentally friendly farming practices and greater flow of farmer knowledge in the community. In addition to greater knowledge and techniques, the way that they their exploration of farming practice in the context of their studies—each grow-

ing their own plot, comparing experiences, experimenting with techniques they hear about, inviting neighbors to see their demonstration plot, sharing what they learn with local farmers and asking about their practices—encourage the development of a culture in which farmers ask questions, learn from their experiences and share insights with one another.

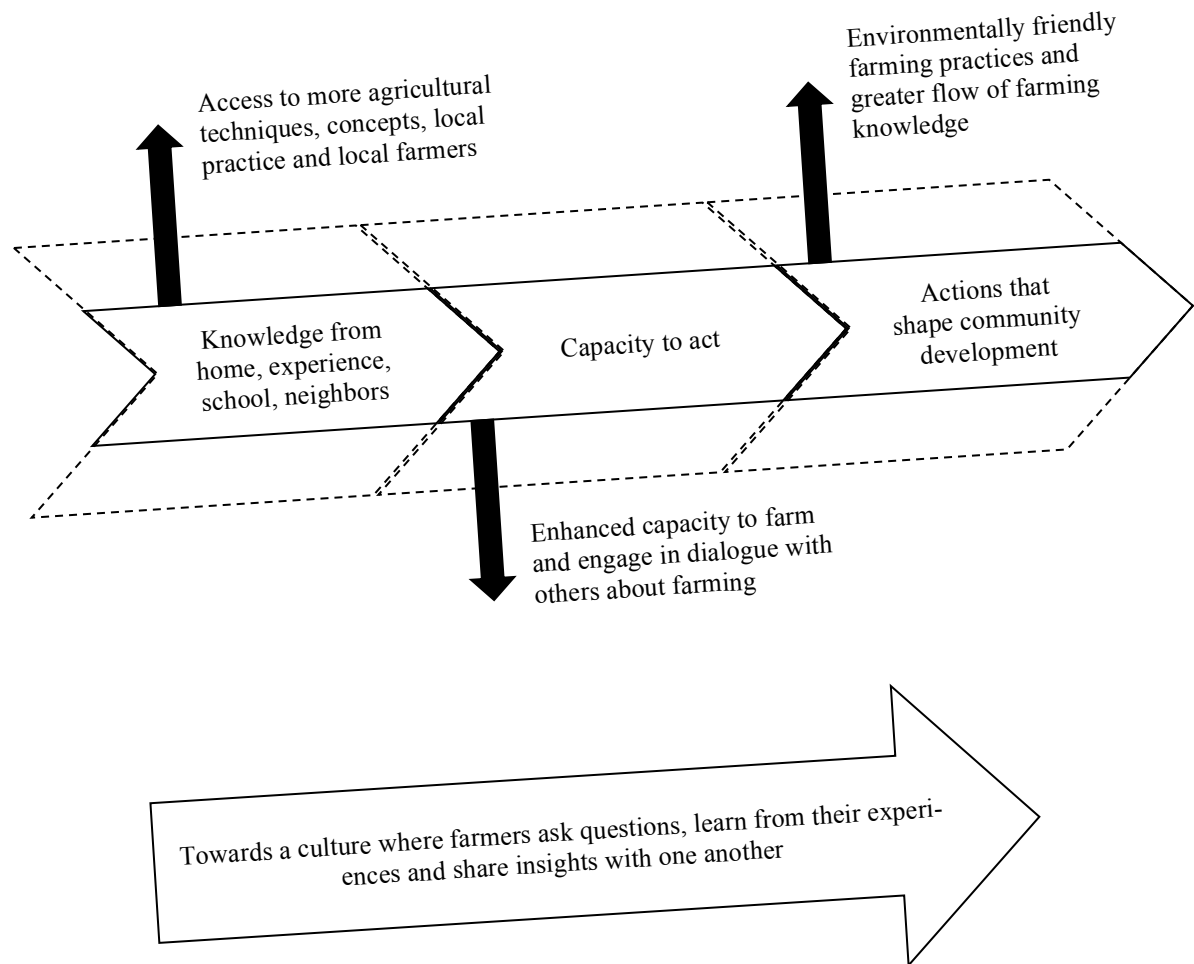


Figure 7. Model of Jason and Kolwe 1's Use of Science Learning For Community Development

Conclusion

Epistemological beliefs are but one of many elements of the figured worlds of science learning that impact how science may be used outside of the classroom and contribute, in that way, to community development. The case of PSA in Zambia demonstrates that in a learning environment in which knowledge is considered the product of an exchange between multiple sources, the patterns of interactions within the classroom translate into patterns of knowledge-sharing with others, where the knowledge and reasoning ability of others is respected and built upon. Such findings set the stage for thinking about the interaction of local knowledge and modern science, a question of great concern in science education, science studies, and development, and the subject of the next chapter.

CHAPTER IV

SCIENCE, LOCAL KNOWLEDGE, AND COMMUNITY DEVELOPMENT

The previous chapters have drawn upon the sociocultural perspective on learning to begin framing how science education might contribute to community development, drawing on the case of the PSA program in Zambia as the concrete means of exploring the implications in action. After framing the question and the case in the literature in the first chapter, the second chapter invoked the construct of ‘critical science agency,’ and explored both its strengths for orienting inquiry into science education for development, and some of its limitations. In light of those limitations, and on the basis of experiences within the PSA program, the construct of science agency was re-envisioned in a manner that (a) gave priority to uses of science outside of the classroom, rather than focusing primarily on exerting voice in the classroom, and (b) considered more fully the potential collective benefits of science agency. Ultimately, the chapter put forth a simple model of how science agency can contribute to community development through building capacity and thereby enhancing agency.

The third chapter built from that model to explore what it is that contributes to the development of critical science agency. Taking from sociocultural theory the idea that learning occurs in communities of practice characterized by a shared system of meaning and values, the chapter examined how the development of agency includes more than forging skills and acquiring information. The meaning and values implicit in the community shape the manifestations of agency that result. Specifically, the chapter examined

how conceptions of knowledge promoted in the program impacted student agency and the means by which students utilized what they were learning.

Having explored in some depth how science learning can foster an enhanced capacity for certain practices and behaviors that might influence community development, it is now possible to address the topic of community development itself more fully and return to some of the key questions identified in the first chapter. How can community development be framed and approached so as to move beyond the many pitfalls identified in development literature? Given concerns that science displaces local knowledge, culture and beliefs, what role can and should it play in community development? What relationship between modern science and local knowledge is appropriate for science education for community development? While these questions are most frequently discussed at the theoretical level, as seen in the introduction (e.g. Kyle, 1999; Savage & Naidoo, 2003), the PSA program in Zambia offers an opportunity to examine concretely a particular theory in action, thereby enriching the discourse. This chapter complements the previous two by placing discussions of science education for development in the broader context of debates around global justice.

Problems of Science and Knowledge in Development

As noted in the introductory chapter, international development is an endeavor fraught with problems. As it was framed by Truman's Four Points, it rested on the assumption that 'the rest' should be remade in the image of 'the West,' economically, politically, and socially (Rist, 2002; Sachs, 1992). This became a ruling binary that cast all nations as either 'developed' or 'developing,' and identified each country's strengths and

needs on that basis. ‘Developing’ countries were recognized only in terms of poverty and the resulting problems of access to health care, education, infrastructure, among others. ‘Developed’ countries, in contrast, were considered free of such problems, and as such were responsible for helping to alleviate the suffering in other nations. The consequences of framing development in this way were numerous. The ways of life, knowledge, beliefs, culture, capacity, and innate potentialities of a majority of the world’s population were entirely disregarded and deemed inferior. Coupled with theories that economic endeavors should be guided by self-interest, such framing has led to projects and funding in the name of charitable international development that in the long run profit the benefactors more than the supposed beneficiaries (George, 1997). Projects have been undertaken according to the sensibilities of outsiders, often at odds with local ways of life, and with little to no long-term commitment or vision (Ferguson, 1997; Galeano, 1997).

Within this conceptual landscape arise questions around the role of science in the development endeavor. Those deeply rooted in the aforementioned assumptions of development, and draw on beliefs articulated by Truman himself, see science as something ‘the West’ possesses that can benefit ‘the rest’ if gifted to them through development. This can take the form of particular technologies or higher education training to utilize those technologies. Critics, however, argue that such a stance ignores the knowledge already present in countries deemed ‘recipients’ of development (Alvares, 1992; Shiva, 1997). This knowledge, they hold, is integrated with and constituted by the beliefs and culture where it is found, while ‘Western’ science brings with it culture and values that undermine local beliefs and practice. While disregard for modern science might offend Western tastes and preferences, as would the use of neem sticks instead of toothpaste, for

many parts of the world it, according to these authors, does more harm than good. Instead, traditional and local knowledge should be left to properly govern social affairs.

This chapter delves more deeply into this debate by exploring two primary topics that give it shape: (1) how local knowledge (or ‘traditional knowledge’ or ‘indigenous science’) should be viewed and why it should be included in both the teaching of science and in considerations of development; (2) what is meant by community development and what role knowledge should play in it. In each case, the chapter examines the strengths and weaknesses of various positions within the literature and then returns to the case of PSA in Zambia to understand where that experience fits and what it might contribute to the debate. In so doing, the chapter pursues the objectives of phronetic social science research (Flyvbjerg, 2001).

Framing Local Knowledge

In the literature: A false juxtaposition of indigenous knowledge and modern science

In both science education literature and development literature, the topic of local knowledge (also referred to as traditional knowledge or indigenous science or a number of other terms, depending on one’s stance) is one of great import to those concerned with social justice. Some would argue that neglecting local knowledge is one of the remaining vestiges of colonialism (e.g. Harding, 1998). Addressed in the fields of both science education and development studies, the question of local knowledge is vital to discussions of science education for development.

Before delving into the topic further, it is useful to establish an understanding of the way certain terms are being employed in this paper. Discussions of science and local knowledge have invoked an array of terminology including: local knowledge, traditional knowledge, traditional ecological knowledge, indigenous knowledge, indigenous science, African science, local science, global science, modern science, Western modern science, white male science, and school science. Choice of a given set of terms has both political and epistemological implications. Use of ‘indigenous science,’ or ‘African science,’ for example, reflects political concern for equity among cultural traditions and indicates the perspective of there being multiple sciences tied to particular cultures or worldviews. ‘Science’ in this perspective is conceived of as a sort of “tool to answering existential questions and making sense of the connections of people to their cultures, nature/Earth and society” (Asabere-Ameyaw, Dei, & Raheem, 2012, p. 19). It need not all be a product of a particular process but rather is characterized by its intention to explain and make sense of the world. This does not conform to the view of science identified at the outset of this paper, which has framed science as a universal human enterprise to which many societies have contributed and from which all societies many find benefit. As such, ‘science’ will not be used in the plural. The paper instead uses terms such as local knowledge, traditional knowledge, and indigenous knowledge interchangeably, though they have slightly different connotations: local knowledge would include knowledge linked to the local context, both knowledge that has been passed down across generations and knowledge that has recently been generated about the local reality; traditional knowledge suggests knowledge that is passed down over generations and in possession of a majority of the adult population (Gitari, 2012); and indigenous knowledge has a similar

meaning but seems to emphasize a dualistic distinction between ‘indigenous’ and ‘non-indigenous’ people that does not reflect the complexity of life in most parts of the world (Ellen & Harris, 2000). For these reasons, the term ‘local knowledge’ is favored in the paper, but not used exclusively, and ‘indigenous knowledge’ is used more sparingly except in reference to literature that relies upon that phrasing.

As researchers and theorists have advocated for greater inclusion of local knowledge in the teaching of science and the approach to international development, justification for its place in these fields has usually relied on the implicit argument that indigenous knowledge is a system of knowledge separate from but equal to modern science—if not in its explanatory power, in its ability to create meaning, explain observations, and rule decision-making (Asabere-Ameyaw, Dei, & Raheem, 2012). Each system, it is argued, is integrated into the culture in which it developed; to introduce one system to another is to impose an external culture. They are often described in terms of opposing characteristics: modern science is purportedly systematic, objective, universal, detached, and rational, while indigenous knowledge is considered context-dependent, practical and characterized by a connection between the knower and the known (Agrawal, 1995; Nygren, 1999). As such, the two are regarded as incommensurate systems of knowledge, both of which should be recognized and appreciated for the sake of student learning and of justice (Asabere-Ameyaw, Dei, & Raheem, 2012).

These assertions oversimplify reality out of concern for congruity and crude notions of justice. More accurately, science and traditional knowledge are not complete opposites, nor are they congruent, nor entirely separate from one another. One problem with simplistic assertions of congruence is trying to determine what should be considered

traditional knowledge. Local classification schemes for plant life are an obvious choice. Often traditional technologies and values and attitudes toward nature are included. Indeed, the areas of agriculture and ecology are most often addressed in the literature (e.g. Acre & Fischer, 2007; Blaikie et. al, 1997; Cleveland & Soleri, 2007; Dove et. al, 2007; Nygren, 1999). Some critics argue that such discussions of indigenous knowledge revere content that is similar to modern science, while discarding the underlying epistemologies, which differ (e.g. Briggs, 2005). In the case of Brigg's critique specifically, he did not articulate in more detail what he meant by this nor did he provide any illustrative examples. While classification schemes and effective technologies are easy to support as valuable indigenous knowledge, it is less clear whether traditional metaphysical beliefs and explanations should be included, such as witchcraft (Agrawal, 1995). Often, these elements are considered an important part of the traditional knowledge system that cannot be divorced from other elements of knowledge and aspects of culture (Asabere-Ameyaw, Dei, & Raheem, 2012).

Furthermore, it is in most cases not true that traditional knowledge and modern science are entirely separate systems. Speaking to traditional plant classification in eastern Indonesia, Ellen (2007, p. 64) described, "scientific and folk classification have co-evolved in recent global history, and the relationship between folk knowledge and instituted scientific knowledge can be modeled as two interacting and mutually reinforcing streams." Similarly, Dove et. al (2007) identified a number of examples of what they refer to as 'hybridization,' in which scientific knowledge and local knowledge are brought together in various efforts, for example, forest protection in the Sierra Juarez mountains in Mexico. Just as modern science is not simply the product of European innovation

(Bernal, 1987; Harding, 1998; Sardar, 1989; Tilley, 2011), what is termed indigenous knowledge is not usually the product of a single isolated group of people.

Questions of the nature of indigenous knowledge affect discussions of what role it should play in science education and community development. To orient the look at local knowledge in the PSA program, two distinct positions on local knowledge in science education, and their implications for community development, are explored below.

One well-known argument for the inclusion of indigenous knowledge in science education was proposed by Aikenhead and Jegede (1999). Drawing from their own separate research in Canada and Nigeria, they highlighted what they saw as cultural dissonance between school and home life. They described the experience of learning science as ‘border crossing’ into the subculture of school science from students’ everyday-life worlds (Aikenhead, 1996; Aikenhead & Jegede, 1999). Discord between these two worlds creates a sort of cognitive conflict that students have to be assisted to navigate successfully. More specifically, in school students in non-Western settings, students construct parallel systems of meaning around concepts, compartmentalizing school science and traditional knowledge as separate from one another (Aikenhead & Jegede, 1999; Jegede, 1999). Aikenhead and Jegede referred to this process as collateral learning and warned that if science teaching did not take into consideration the traditional worldview of the learner, it would risk destroying the framework upon which students rely to make sense of the world around them. The type of science learning that these authors advocated, then, relied primarily on code-switching between what are considered entirely distinct figured worlds. Their concern was not so much the use of science outside of the classroom, but rather effective learning in the classroom, given students’ life experiences. Ul-

timately they wished to raise the quality of science teaching and learning by recognizing local knowledge and students' previous experiences. Such a position would seem to support science education for development primarily through greater representation in science. Helping students to cross the border into school science allows more 'non-Western' students to enter into the field of science and contribute back to their communities in that way.

The position of Aikenhead and Jegede is common in the field of science education. It acknowledges that ignorance of students' previous experiences and the frames of thinking that they bring with them can be a major impediment to their science learning. By addressing this, it aspires to a more fruitful learning experience for students of different backgrounds, who will hopefully become more represented in the field of science. The problem with this approach is that it dooms students to code-switching, holding incompatible beliefs in their heads and drawing upon one or the other, depending on context. This would seem to lead either to fragmentary thinking (Bohm, 1981) or ultimately settling on one knowledge system or the other depending on one's choices after high school. While this approach may improve test scores and student representation, it does not seem to be very useful from the perspective of how students might use science outside of the classroom.

A distinct orientation to local knowledge in science education was identified by Van Eijck and Roth (2007). They cast debates around the role of indigenous knowledge in science education as a disagreement between the incompatible frameworks of multiculturalism and universalism. Multiculturalists consider all systems of knowledge to be embedded in the context of a cultural group, including 'Western science,' and they worry

about the destructive effects that the spread of 'Western science' can have on the knowledge systems of others. For this reason, they advocate teaching multiple systems of knowledge and making explicit for students the influence of cultural assumptions on the work of science. Universalists, on the other hand, assume the existence of a natural world external to and independent of human construction. They single out science as special among systems of knowledge and belief in that it is able to make statements about that external reality that transcend local context, that are valid everywhere. On the basis of this analysis, Van Eijck and Roth (2007) see the stalemate between the two factions as resulting from inadequate considerations of epistemological difference. While universalism is concerned with the relationship between knowledge and material reality, multiculturalism is directed at the relationship between knowledge and cultural reality. Both, according to these authors, erroneously view culture and knowledge as static, singular, and homogenous entities that neither change over time nor vary among participants. Furthermore, these views are not attentive to the distinction between 'truth' and usefulness. In response, the authors recommend an epistemological stance that considers knowledge to be connected to both material and cultural reality, that emphasizes usefulness over "truth," and that recognizes knowledge and culture as changing and heterogeneous. To illustrate the implications of this position, they examine two texts regarding a salmon run, one from a scientific journal and the other an "Origin of the Salmon" story from an unidentified WSANEC storyteller. In practice, they explain, both narratives represent forms of knowledge that may be drawn upon to solve problems and make decisions. Meanwhile, neither narrative can be reduced to the other; the second lacks the quantities and

units central to the story of the first, while the first lacks animism and other concepts central to the second.

Van Eijck and Roth's (2007) analysis of the fundamental assumptions underlying debates of multiculturalism and universalism offers useful insight for the discussion at hand. Epistemological considerations of whether knowledge is primarily reflective of material reality, cultural reality or both, of whether knowledge is static or changing, and its relationship to both usefulness and truth are all worth making explicit in discussions of science education for community development. The position identified by Van Eijck and Roth themselves appreciates the input of multiple perspectives on a single topic, in this case the salmon run. The description from a scientific journal article on the topic provides a detailed account including how long it takes for the eggs to hatch, the stages that come after hatching, and how long is spent in each subsequent stage. The "Origin of the Salmon" story tells of brave young men who set out in search of salmon, and met 'salmon people' who gave them instructions on how to treat the salmon well and find and catch them. The story has a number of lessons valuable to the WSANEC people in conveying how to catch salmon. According to Van Eijck and Roth, while the science account is the only one that would be considered universal, both are *useful*, which is of greater interest to them. They warn that "if we aim at 'truth,' that is, the relation between concept and material reality," then the "price to be paid for scientific knowledge to *apparently* transcend local contexts" is that "the local artifacts that are bound up with these contexts need to be modified or deleted" (Van Eijck & Roth, 2007, p. 939, italics in original). Yet, Van Eijck and Roth's disregard for truth is unwarranted. That the WSANEC story of the salmon run is locally valuable may merit its inclusion in the context of a study of the top-

ic, but it does not make it unnecessary to seek out universal patterns in the constitution and behavior of the fish. The two accounts are not equally valid when weighed against material reality, but the merit of the origin story does not lie in its validity. It connects the listener to his or her people, to their history, to their land and their dependence on it for sustenance. And it conveys and reinforces traditional techniques for salmon fishing. The concern of Van Eijck and Roth for “usefulness” over “truth” in the context of science education seems to imply that science, or the contents of the science lesson, somehow have broader implications of social value—that if something is not accounted for in science education then it is deemed less valuable. Yet this need not be the case. Might science education concern itself with truth, with the link between knowledge and material reality, without alienating local beliefs and traditions?

This discussion provides the basis for exploring conceptions of local knowledge in the PSA program and the implications of these for the approach to science education for community development. Specifically, the section that follows asks the questions: How do participants regard local knowledge in the context of their studies? How, if at all, do they relate it to science? These questions set the stage for thinking about science and knowledge in community development in the next section.

Local knowledge as a conversation partner: “We make them to talk to each other, and see... how they go together”

In interviews, the topic of science and local knowledge most commonly came up on the subject of agriculture. As participants were asked about what stood out to them in their experiences and ways that they had used what they were learning, over and over participants remarked that through their study in the program they came to understand the

reasons behind traditional practices. This seemed to be one of the things that several appreciated greatly. For example, one person (Tutor 1M) explained:

In DHE, when it came to this component of mixing the crops, it's one thing that interested me the most, because at one point I used to ask my grandpa to why they are mixing there the crops. They would just give this understanding to say, 'no they must grow together and support each other.' But now I came to understand the scientific part of it, that some are nitrogen-fixing like beans, they help the maize.

A student (Pushi 3F) similarly commented:

In our community many people plant maize and beans together in one plot. It is just what is done, because that is what our grandfathers also did. But then with studying "Planting Crops," I have finally come to see why, because the bean plants are helping the maize to get nutrients.

She continued, drawing larger conclusions about the relationship of science and technology:

This was so interesting to me because before I was just thinking that maybe people did this to save time or they needed enough food, but I didn't know there could be maybe a scientific reason. I am seeing now how our traditional knowledge and science they go together. They are teaching the same things.

In describing the scientific explanation of this traditional practice, others too drew broader implications. For several, it illustrated that multiple sources of knowledge need not conflict, that there is wisdom in traditional ways, and that both traditional and modern knowledge are beneficial to the community. One participant (Tutor 3M) explained:

We learned a lot because we find some of this knowledge that we are learning, they exist in community so there is just a need to see how we can incorporate and how we can work together with traditional knowledge and this modern knowledge, because you find that people are planting maize and beans, they are just planting these for the sake of maybe to have the yield. They don't know that there is even nitrogen fixing... It's natural, they have been just doing it... So in the community there is this plenty of knowledge which needs to be harnessed, and it has to be integrated with this new knowledge which we are learning so that we see which way forward.

Another (Tutor 18M) echoed:

We have learned on how to use both new technology, also to use the old wisdom that our old people used to use. So PSA is really working in the way that they are encouraging us to have that balance, because if we look back in the olden days, I'm sure these people never had these chemicals, but they were able to have crops. I think what made it possible is that same method of having different types of crops planted on a same land, which had an advantage, you know. And it's some of the things I've learned from PSA as well, so I recommend PSA... because the thing is, even there are other educational institutions where they have, you know, like reached a point of abandoning the old methods that have been existing... so I really return to this, which is educating us on how to work with both knowledge. Yes.

Similarly, one of the students (Pushi 4F) described:

The way I am seeing we have both this knowledge we are learning in PSA and the traditional knowledge of our forefathers, and it's like we have a conversation between them. We make them to talk to each other, and see which one is helping or how they go together in what we do.

For these participants, it seems, an orientation to knowledge that encouraged wide participation and insights from multiple sources, as seen in the last chapter, fortified an appreciation of local knowledge and practices as complementary to those coming from science. Having specific instances of traditional knowledge that they came to understand better—for example, the idea that maize and beans should be planted together—formed the basis of more abstract beliefs about the relationship of local knowledge to science.

While the example of beans helping maize to grow through nitrogen-fixing was the most common one mentioned in interviews, a couple other instances connecting scientific explanations or practices to local practice were given. For example, Kaweme, a coordinator, described:

The same plants we are seeing today, they act as medicine to some of the diseases. So trees, for instance, there is this traditional knowledge, you know when, like I've heard and I've used that one before, when you have

stomachache, you just go and pluck off the mango or guava tree, and then you chew. (EL: The leaves.) The leaves, yes. Then after chewing, that pain goes off, you know, so already it's medicine, so it's science that is working there. Because, and it's true, the bitterness that you get when you are chewing, it's very bitter, it's the same bitterness I experience when you take these drugs that I have experienced, that are coming from, for [lack of a] better term, they call them Western medicine, you know. When you take, what's this, Flagyl, it's very bitter, you know, it's the same. Now the question is, is it that bitterness that deals with the bacteria or what? You know. So you can say that it also helps.

As in the other example, a connection or sameness between traditional and modern knowledge was identified. In this case, he found that the traditional treatment for digestive problems had a similar taste as the Western medicine and hypothesized that this reflected a similarity between the two technologies.

The idea of integrating local knowledge and science, putting them into conversation, was reoccurring in the description of participants. Yet it did not imply that they would always agree. Not all the science that students learned served to reinforce local practice. Sometimes it had cautionary implications for common local practices. In some cases, there were warnings against the unproblematic use of modern technologies, such as chemical fertilizers and pesticides, which were extremely common in the region, as described in the previous two chapters. Explanations of the characteristics of the soil and the physiology of insects offered alternative options that were cheaper, longer lasting, and/or less harmful to the environment. In other cases, scientific descriptions uncovered potential hazards of traditional practice, such as slash-and-burn techniques, which kill helpful organisms in the soil, and practices in the northern part of the country to use soil for a few years until it becomes infertile and then move to a new plot. One tutor (18M) explained:

Some of the methods we are using traditionally on our farming system are good, you know, as they all help in crop production... but [others] may bring negative effects. [The tendency in our region is] I use the land for 2-3 years, I shift to a different land, and the challenges now at the moment is we do not have available land nearby [anymore]. So now we are going very far to access land... In PSA, we have seen the different kinds of nutrients that the soil needs. Fertilizer can give back some, but it is expensive. If we also use other techniques, like tea and chicken manure, preparing the soil with greens and browns [burying grass and dried leaves, etc], furrows, then we can build back the fertility and don't have to keep moving. Also, we shouldn't cut down all the trees because the soil fertility gets washed away. Even we tried a project to plant acacia trees, which are nitrogen fixers, with other farmers.

In this case, greater knowledge of soil biology helped identify shortcomings of the local practices that included cutting down trees and abandoning land after it loses fertility.

Another student (Pushi 6F) similarly described:

M 6F: [In our research activities with farmers,] as we went around asking them, we came to advance according to what we knew and what they were telling us, so we added to what we knew... like there was a method which they were using like a *chtemene* system.

EL: What's that?

M 6F: ...it's the traditional methods which are found in Zambia, more especially the Western province and Central province, which is this province. Yeah, so, maybe they cut over trees and burn them. So us we did not know that, so we came to learn... The reason for doing this is because if you burn those trees, the land won't produce many weeds. That is the good reason. But also, according to what we learned in "Planting Crops," I had to ask myself some questions. If they are burning all the land, what happens to the microorganisms and bacteria that live in the soil and help plants to grow? We learned about these, and so I am asking myself this question.

EL: What do you think is the answer?

M 6F: I don't know yet. I still have to investigate on that one.

In this case, learning about soil microbiology did not lead to decisive condemnation of local practices—the student was not sure and not growing food herself at the time of the interview and had never used the *chtemene* system—but it did raise its efficacy as a question. In other examples, depending on how one uses the term 'local knowledge,' one

could potentially consider the common misconceptions about the causes of malaria mentioned in the previous chapter to be local ‘knowledge’ that was contradicted by the science introduced in the program.

The comments of participants, then, indicate that they were indeed putting local, traditional knowledge into conversation with the science they were learning—both at the level of specific instances, for example explanations of how different local practice affect the soil positively and negatively, and drawing from these instances broader conclusions. Most striking to students were the ways in which scientific explanations elucidated and reinforced traditional practices. Yet, there were also times when they called into question local practices or common local beliefs.

Critics (e.g. Briggs, 2005) would argue that this orientation to knowledge lends primacy to science, at the expense of local knowledge. Rather than respecting the autonomous value of traditional knowledge, participants are weighing its value against science, appreciating what overlaps and disregarding anything that contradicts, like potentially the *chtemene* system of burning land before planting. Such authors worry that this leads to indoctrination in science and the dissolution of local knowledge. Yet, in this case, many of the effects were the opposite. The understanding of certain scientific concepts, such as the necessity of nutrients in the soil for plant growth and the different ways that chemical fertilizers, organic fertilizers and microorganisms all contribute to those nutrients, called into question a number of practices introduced in the region in the name of modernization. They, instead, highlighted and reiterated the value of local practices that had perhaps been less appreciated, or at least, less understood. The example makes clear that promoting scientific understanding is not the same as diffusing Western practices. For

this reason, the distinction between science and technology is key. While modern science makes possible technologies of monoculture, chemical fertilizer and chemical pesticides, it does not necessarily support them as best practice for sustainable agriculture. The insights into reality generated by science can serve as a balance in which to weigh both imported (“modern”) and local technologies. Thus while some, wishing to make science and indigenous knowledge equivalents, have advocated for considering science and technology all one thing (e.g. Gitari, 2012), blurring the lines between the two is actually a cause of the disregard for local knowledge that such advocates are trying to prevent.

In this light, the notion of dialogue between traditional knowledge and science has a meaningful role in the context of larger social trends, particularly in community development. In the experiences of these PSA participants in Zambia, it served as an important means of checking large-scale monoculture farming and its expensive technologies, which entail high risk to small-scale farmers (Shiva, 1991). It challenged the racist vestiges of a colonial system that relentlessly conveyed that everything African was inferior (Banda, 2008). A conversation between local knowledge and science implied that each had something of value to contribute, as Aikenhead and Jegede (1999) and Van Eijck and Roth (2007) would agree. Yet, the comments of students do not seem to emphasize the distance between local knowledge and science to the degree that Aikenhead and Jegede do, nor did they imply disregard for truth as Van Eijck and Roth advocated—this will be explored more in the next subsection.

Re-appropriating 'Science': "Normally we say we have this traditional knowledge, but we don't think it is scientific."

In addition to the ways in which several participants described traditional knowledge as complementary to modern science, in a few instances practitioners expressed a relationship that went even further than complementarity. They came to describe local knowledge as scientific. One instance is seen in the follow excerpt from field notes:

After four days of an inter-organizational consultation about PSA in Africa, a few of us stood outside waiting for the refreshments to be ready during a mid-afternoon break. At a lull in conversation, I brought up a discussion from the previous day, saying to Ali, the national coordinator: 'Mr. Tiati really wasn't a fan of our approach to killing snakes.' Ali explained to everyone his personal policy on snake encounters: first you kill them, then you find out whether or not they were poisonous. 'Better than finding out the other way,' he explained. I joked that it would be useful to have a smart phone app that identified snakes by simply taking a picture of them. Ali told the story of our tall, powerful security guard instructing everyone to wait before killing a snake found on the property until he could look up in a book whether or not it was poisonous. The reference book confirmed its dangerous status and it was killed.

Somehow the conversation got onto the topic of treating snakebites. Perhaps Gregory himself was the one to broach the subject. He said there was a tree in Mwinilunga where he lives that is used to treat snakebites. In contrast to anti-venom, which according to Ali is mostly produced in the US, made using venom collected from snakes and only effective in treating corresponding snakebites, powder made from the tree could be used to treat all types of snakebites. And it treats them really well. If you apply it topically to the location of the bite, it won't even swell. 'But you know,' said Gregory, 'the way our people came to know that this tree could treat snakebites is very interesting. There is a certain animal that fights with these poisonous snakes [a mongoose]. People watched it and noticed that every time it got bitten it would climb a certain tree and eat the bark right away, then return to the fight.' The rest of us commented in amazement.

'That is really scientific!' Ali remarked.

So impressed was Ali that the next day, on our trip to Lusaka to meet with the Inshindo Board, he brought the subject up again. Gregory, Ali, Kaweme and I were seated in the back of a car turned mini-van (an extra row of seats had been squeezed in what was once the trunk area). 'I am still thinking about the snake treatment you mentioned,' he said to Grego-

ry, ‘that was really scientific. Usually we want to classify something as scientific when we look at the tools we are using to find it.’

‘Or if it comes from the West,’ Kaweme added.

‘It is so scientific,’ Ali continued, ‘Normally we say we have this traditional knowledge, but we don’t think it is scientific. We don’t think about how it came about. They observed their environment, identified patterns, and made hypotheses about how the tree bark might counteract the effects of a poisonous snake bite.’

‘Yes, they even tested different ways of using it,’ responded Gregory. ‘First, I think they tried eating it. Only over time did they come to dry out the bark and grind it into a powder that is placed directly on the bite.’

In this excerpt, the group identified the snakebite remedy in Mwinilunga as scientific because of the manner in which it came about—through observation, analysis and experimentation. They contrasted the categorization of this knowledge as scientific with what they considered more typical characterizations of science, as something requiring certain instruments and as something coming from the West. In this case, it was local Zambian knowledge they saw as scientific (and interestingly, superior to the anti-venoms common in Western medicines in terms of the wide range of its applicability). Science became something that was local and indigenous to their land and the practices of their people, rather than something only available through importation.

In another instance, a group of coordinators consulted on ways to assist students with their desire to learn to plant trees for the environment:

Mapalo, a tutor from the West raised a topic in hopes of finding support from the office administration for a project identified by several groups. He explained, ‘We want to see how the projects team can help us with tree planting projects, especially since the rainy season has recently begun. There are four groups in the West interested in this project.’

Alex, also from that region, elucidated, ‘We appeal to the projects domain that we build a relationship with the Forestry Department because they have seeds and nurseries, and it will be cost effective. Maybe they are looking for people to work with who have knowledge and interest in this area.’ As everyone at the meeting knows, PSA groups in the northwest of the country have met with some success collaborating with the Forestry

Department, who trained groups of PSA students to care for a plantation of non-native pine trees...

Kaweme responded: 'We are waiting for their call. We went there after the study of "Ecosystems," but they did not like us, judging by the way they responded. We went with Ali to the provincial office, then the district office. They were saying, this is a very difficult thing. She was demoralizing us, saying your students can't manage. They said they would get back to us when they had something.'

The national coordinator suggested a way to strengthen the relationship with the Forestry Department in order that future collaboration might be possible. Several in the meeting voiced agreement with this plan...

After a few more thoughts about ways to collaborate with the department, and reasons why it is beneficial, Kaweme introduced a new line of thinking. 'How about consultations at a group level? What of trees around you instead of exotic trees from a nursery? A group in Mwinilunga started planting wild seeds to see which were able to germinate.' Mapalo mentioned the possibility of getting acacia seeds, and Alex suggested groups try planting mango and guava from seeds all around. Kaweme asked the group to think about what would be necessary to plant these types of trees. 'How can we learn to germinate and propagate mango? Popo [Papaya]? For example, someone I know tried to dry mango seeds on the roof. But mango seeds need to be planted when still fresh. Another option is to just pick from the ground ones that have already germinated.' Two coordinators suggested experimenting with the germination of different types of common seeds to learn how to grow seedlings.

Alex shared a relevant experience. 'There's a woman I know who just picks avocados that others throw that have germinated and sells them. Chibwe was very curious, but me I didn't pay attention. Apparently you have to orient them in a certain way. This woman wasn't even a PSA student, but she was working very scientifically to see how doing certain things leads to germination or not.'

Kaweme used the story to make a point. 'There's knowledge in the community. That's one thing we're trying to help students realize. There's knowledge, like this lady. The older people I am sure know how to grow local species.'

Alex agreed. 'This lady just knows. Even apple seeds they germinate for her, but not when I do it.' This idea reminded Alex of another thought. 'Drawing from the idea in "Planting Crops," maybe we can start a seed bank.'

'At the unit level?' Mapalo asked.

'Even at the group level we can do it,' Alex responded.

In this case, too, one of the coordinators characterized a local woman's efforts as scientific. Though she had not been taught about growing trees through formal training, she

was on her own testing out different practices and learning from experience how to grow various fruit trees. The local knowledge of this woman was generated through a scientific approach that asked questions, tested hypotheses, and sought patterns—a contemporary example of the kind of thinking that was behind the snake treatment account.

Also of interest in this interaction is the transition of the group from one strategy to help students learn to plant trees to another. Their first tendency was to try to seek knowledge and resources from established, prestigious sources, such as the Forestry Department. This had been successful in other regions and fit with the program's efforts to connect to local resources, specifically a local agency of the government. The problem in this case was that the Forestry Department did not seem to want to work with them, thereby impeding the development of a project. Through further consultation, however, specifically at the suggestion of Kaweme, they started thinking about possibilities outside of established, prestigious sources of knowledge. Through this line of thinking, Alex recalled a woman who experimented a great deal in this area and seemed to have considerable knowledge, a woman to whom Alex admits he had paid little attention. In this way, the conversation also exemplifies a changing orientation to resources, recognizing and valuing local resources that had previously been overlooked. This echoes sentiments of other participants, mentioned in previous chapters, that through their studies they came to recognize knowledge they had not previously known existed in their communities. The idea of starting a seed bank mentioned at the end reiterates this point of creating systems to draw on local resources, rather than continually seek external expertise, in buying engineered seeds for example.

By describing particular instances of local and traditional knowledge as scientific, participants were recasting hierarchies of knowledge (Janzen, 2008). While Jegede and Aikenhead (1999) emphasized a barrier between traditional knowledge at home and school science, in these cases students were using the “knowledge, practice, and context of science”² to interrogate traditional knowledge and rethink its place in their worldview. As they learned about scientific reasons for traditional practices, they came to see those practices and that knowledge not simply as cultural tradition—as their previous reasons for using certain gardening practices were because that was what their parents taught them to do—but as knowledge that captured certain aspects of reality more than they realized, and more importantly, as knowledge that was generated in a manner with the same characteristics of the knowledge that had been introduced and revered from outside. From this perspective, science was not a Western practice to be embraced as one of the positive legacies of colonialism, but rather something indigenous to the people and the place. At the same time, what they were calling scientific was not considered a separate ‘African science’ to be compared and contrasted with the system of knowledge that led to the atomic theory of matter. Rather, it was a manifestation of the same innate human capacity underlying modern science, though passing through different social structures and institutions.

Such considerations of local knowledge and its relationship to science set the stage for thinking about the role of knowledge in community development, which is explored further in the next section.

² as described in Calabrese Baron & Tan, 2010

Community Development and Knowledge

In the literature: Beyond the economics of community development

In the same way that the worldview and practices of PSA challenged dichotomies in the debate around science and local knowledge in the literature, they also provided a means for reexamining the topic of community development. The introductory chapter of this paper indicated that development would be addressed here at the community level, in part in order to avoid the common approach to international development as ‘catching developing countries up’ to the standards and ways of life of ‘developed’ ones. Community development reflects a need for attention to progress and well-being in each country, and each locality within that country. As it is taken up here, it implies attention to questions of justice and equity, access to goods and services, but also to opportunities to contribute meaningfully to the collective. In order to better situate views of community development within the PSA program, this section briefly examines a few considerations in community development literature and participatory action research.

According to DeFilippis and Saegart (2013), community development has gained momentum in the U.S. in the last four decades, evolving from a small-scale effort in which a small number of organizations fight “seemingly quixotic struggles to improve the conditions and quality of life in a few poor urban neighborhoods” to a commonplace set of institutions and practice (p. 1). Globally, it has similarly grown in size and institutional structure, particularly influenced by the policies and funding of institutions such as the World Bank and the International Monetary Fund. DeFilippis and Saegart situate community development in theory and in practice between two contrasting social theories re-

garding the relevance of community in modern times. A number of sociologists, such as Tonnies (1957), Weber (1978), and Simmel (1950), predicted that modernization, particularly capitalist urbanization, would disrupt traditional social organization in communities by rendering previous levels of reciprocity and interdependence unnecessary and unlikely as large numbers moved into dense urban environments with high levels of division of labor. Such theories provide something of a conundrum for community development. Filippis and Saegart described:

One of the most important results of this intellectual tradition is that it has left us in a position of struggling to envision the realm of community playing a progressive—that is, forward looking and thinking—role in social change. In short, how can a social realm that is understood to be dying and exists as a vestige of the past, be a central part in the creation of the future? (2013, p. 2)

Oppositely, pragmatists such as Bernstein (1998) and Dewey (1916; 1927) saw in community the potential for more democratic and inclusive forms of society, even among those with differing interests and ways of life to those living in cities. In this latter tradition, DeFilippis and Saegart find “the grounds for the idea of community as a space for contesting the social costs of capitalism to working class and marginalized people” (p. 2).

Notably, community development, as described by DeFilippis and Saegart (2012), takes place in the context of global capitalism. Communities represent sites where global political economy plays out, though they have limited possibility for transforming that economy. Still, they have an important role in social reproduction through education, housing, health care, and other factors that shape our lives. According to DeFilippis and Saegart, community development is the response that emerges to the limitations of the political economy of capitalism in fulfilling the needs and desires of those living in the

community. Through community development, tools, strategies, and institutional structures can be rearranged and refined to make the most of a limited resource base.

For DeFilippis and Saegart, then, community development is closely linked to economic development, specifically in addressing the shortfall of economic policies and practice, through the actions of some—some organizations and groups—for the benefit of others, usually the poor and disenfranchised. While DeFilippis and Saegart were largely attentive to the reality of community development in the U.S. context, similar understanding of community development characterizes the descriptions of others that have a more global vision in mind, such as Daly and Cobb (1994) and Campfens (1997), though some may place greater emphasis on the role of the community to make its own decisions regarding its needs.

While science studied in PSA does hold the potential to address certain needs and desires that are not being met by global capitalism—for example, providing access to pertinent information and techniques related to agriculture, health care, and environmental protection, and generally supplementing the education available to the community—the description of community development above does not seem to capture best the program's contributions to community. The analysis of the program so far would suggest that greater importance on learning and using knowledge. To complement the above considerations of community development, then, it is helpful to take up discussions of knowledge and social change found in other areas of literature. Here we will turn to questions of knowledge and power in participatory action research.

Gaventa and Cornwall (2006) use Lukes' (1974) analysis of power in terms of three dimensions to frame discussions of knowledge and power in participatory action

research. In the first dimension of power, the most common vision of power, party A exerts power over party B by getting the latter to comply with the wishes of the former. The party with power is the one who holds the influence in decision-making settings. From this perspective, according to Gaventa and Cornwall, knowledge is a resource mobilized in the debate. Expertise is used to strengthen one's argument, as in a court case. In the second dimension of power, it is recognized that power can be exerted by allowing some debates to occur while suppressing others. Power is exercised through agenda-setting. In this case, the process of knowledge production itself is important in exercising power, as the rules of science establish the knowledge of some more valid than others, for example experts over lay people, and research funding disproportionately privileges particular paths of inquiry. Empowerment, in relation to this dimension of power, implies expanding who participates in knowledge production, among other things. While the first two dimensions of power both imply conflict, the third addresses ways that conflict can be prevented through the shaping of others' beliefs and inhibiting their own consciousness of would-be grievances. Here, control of knowledge production and knowledge distribution, through education, media and other means, is key to the exertion of power. Empowerment here relies on awareness building through learning and research.

Each of Lukes' (1974) three dimensions of power saw power in the context of repression—power in the sense of 'power over'—and overlooked the productive potential of power, as in the 'power to' do something, the power to act. It is this sense of power that more closely aligns with discussions of critical science agency in the second chapter. Agency as discussed there can reflect a 'power within' (Nelson & Wright, 1995). To overcome some of these limitations in Lukes' account of power, Gaventa and Cornwall

(2006) turned to Foucault's (1977; 1979) analysis of power as a multiplicity of forces constituting social relationships and intrinsic to all spheres of action, and his characterization of knowledge as power. In particular, they find use in Hayward's (1998) application of Foucault's analysis to describe power as "a network of social boundaries that constrain and enable action for all actors" and to direct freedom, then, as having the capacity to act on those boundaries that define the field of what is possible and shape them (p. 2). The characterization of knowledge and power as the same coupled with a vision of freedom as the capacity to shape the limits that define what is possible give direction, purpose, and value to participatory action research for Gaventa and Cornwall. It becomes a means of generating knowledge from alternative perspectives, overcoming some of the limitations implied by Lukes' three dimensions of power, while also serving as a means to raise consciousness and act on the boundaries.

The vision of critical science agency articulated by Calabrese Barton and Tan (2010) and others, and directed towards community development in the second chapter of this paper, would seem to reflect the same aims identified by Hayward (1998) and Gaventa and Cornwall (2006), as expanding capacity to act. Yet, what do such perspectives imply for discussions of community development? Common conceptions of community development, such as the overview provided by DeFilippis and Saegert (2012), convey a perspective rooted in service-providing, whereby organizations, government agencies, and policies address the gaps to well-being created by the prevalent economic system. In many cases, such perspectives are also concerned with empowerment and acting upon the boundaries that constrain action, by mobilizing neighbors to try to shape housing or other conditions affecting their lives (e.g. Saegert, 2006).

The next section will examine conceptions of community development in the PSA program in light of this discussion. It should be noted that the analysis below of community development in the PSA program is rather limited for a few key reasons. For one, at the time of the research the program was still very new. Inshindo was still figuring out what implementation of the program looked like, responding to challenges of implementation as they arose, and working with quite small numbers of students and groups. For that reason, the discussion of what community development looks like in the program cannot be addressed in any comprehensive manner. Furthermore, as mentioned in the first chapter, social and language barriers inhibited the sort of meaningful participation in community that would have better facilitated a thorough understanding of community development. In the short span of the nine months of field research, it was unfortunately not possible to learn the local language and build relationships with members of the community not directly linked to the PSA program, given other research priorities. The discussion below of community development in the PSA program, then, offers an early exploration on the basis of perceptions of the program's participants and analysis of the implications of a few particular efforts undertaken by students.

Development through a community of inquirers: "We started a process which everyone has to embark on and see how we can develop the community"

From the examples captured in previous chapters of students' and tutors' use of science as a result of their study emerges a particular vision of community development, centered on knowledge use and flow. It is characterized by a community of inquirers, individuals interested to learn more together about aspects of their everyday lives. They draw upon knowledge to improve their practice in a few different ways: through new ide-

as being introduced from outside the community, for example, through educational programs, interactions with experts (such as visiting agricultural extension officers or medical scholars), books, newspapers and other media produced outside of the community; through the local sharing of ideas with one another, in informal passing conversations, in the apprenticeship that naturally takes place across generations and in spaces purposefully created for the exchange of ideas; and through their own experiences and interactions with reality, applying the ideas to action and learning from the result. The actions of such a community rely upon particular orientations to knowledge, as described in the previous chapter. These include values that individuals think for themselves, try to draw closer in understanding to an extremely complex reality, and share ideas and draw from multiple sources as needed. In this light, a community develops through the influx of new knowledge, through deeper understanding and appreciation of local knowledge, through greater familiarity with the distribution of knowledge resources in the community and how to access them, and through increased capacity to learn from experience and investigate the local context. The particulars of which techniques to use are less important than the knowledge processes, because the techniques will evolve and continue to be refined, especially if the flow and capacity to use knowledge is strong.

Three experiences, in particular, shed light on the aforementioned picture of community development and how it relates to discussions of knowledge, power, and community development taken from the literature. Each of these will be examined briefly below.

Tree planting in Mwinilunga. After the study of “Environmental Issues,” a few PSA groups in Mwinilunga struggled to figure out steps they could take to protect the

environment around them. Living in a more rural part of the country, solid waste and even air pollution were not as prevalent and so it was difficult to identify how to help lower them, even though these were the primary topics in the unit they had just studied. Instead, students saw another issue as key to environmental health: deforestation. In that region, it was common to clear the land of trees in order to farm, and then have soil nutrients be depleted after a few years, causing the need to clear new land and start the process over again somewhere else. To learn more about tree planting, they consulted the projects coordinator at Inshindo and also a couple groups visited the Forestry Department. From the projects coordinator they learned about acacia, a nitrogen-fixing tree that could over time help restore nutrients to the soil. In different communities, they invited farmers to learn about planting acacia trees alongside the group, and planted a nursery of trees at one of the farmer's homes. At the same time, the Forestry Department taught three groups about artificial trees (which apparently take about five years to mature, as opposed to 45 years for natural ones), and taught them how to plant and care for them. The groups invited community members of all ages to join them in planting a 50 square-mile plot with pine trees and caring for them together by watering, spot weeding, and creating a fire barrier.

The tree-planting project in Mwinilunga does, as DeFilippis and Saegart (2012) suggest, respond to some of the shortcomings of the capitalist system that propagated monoculture as a means of subsistence through participation in the global market rather than the traditional polyculture approaches which had previously allowed the soil to yield fruit for centuries. The Forestry Department, a service-providing agency of the government, had as one of its objectives to collaborate with members of the community in plant-

ing trees, thereby contributing to community development through environmental health and potentially agricultural sustainability, if they were also planting trees that replenished soil nutrients. From this perspective, what is important is that many trees be planted to mitigate the harmful effects of deforestation.

At the same time, looking at the project in terms of its contributions to knowledge, the efforts of the PSA students have extended access to valuable information, skills and concepts regarding environmental health—specifically, a deeper understanding of the importance of trees to the environment, knowledge that acacia plants help restore nitrogen levels in the soil, and the skills of how to care for tree saplings. Here then we have a form of empowerment corresponding to Lukes’ (1974) first dimension of power, empowerment through access to knowledge and expertise. Beyond this, there are certain elements of an approach to using knowledge for community development that students have gained in this project: namely, the capacity to read their local reality and assess its science needs, then seek out appropriate sources of expertise, and finally gather collective will to learn about applying that knowledge together. As students, farmers, and other members of the community learn about raising trees, and their impact on the environment, from the pine tree and acacia tree plots, they can share what they learn with others and beneficial practices can grow exponentially in scale and reach. This is but one example of community development centered on knowledge flow and use.

Environmental clubs in Lubambe. In the Lubambe group in Kabwe, students decided to use what they had learned in “Environmental Issues” to start environmental clubs in two local high schools. Lucy, a graduate of the program explained:

So we wanted to raise the number of young people that were involved in raising awareness to others in the community and everything. So we [wanted to find] a place that was receptive to having a lot of people be involved. Then we thought of two schools that are near our community... So we had a one-day orientation with the teachers. We oriented them on why we felt it was necessary to... raise the number of young people that were involved in raising awareness about our environment... So from the teachers, we asked them how they could help us now engage their pupils... So they told us then this program, the Environmental Issues project, should be like a club at a school, so it can meet every Wednesday with their pupils. So that's how we started... Then [at the other school] as well, we did the same thing... Together they were 168 [students total in both schools]... So both schools did an investigation on how much waste each shop was wasting, how they disposed of their waste. So they investigated at the market and they also investigated at the shops. Asking the shopkeepers how much waste they had, how they disposed it, possible ways that they thought that they can reuse that waste.

In these weekly after-school environmental clubs, the PSA students helped the high school students do exactly what they had done just weeks before in their study of "Environmental Issues": Students were divided into groups of about 20, together they studied photocopies of the text, and then did the research activities assigned in the book, visiting shops to study purchasing habits, analyzing solid waste content in dumps, discussing with others their waste management practices, and sharing with others their findings.

The example of the environmental clubs in Lubambe is another instance in which community development can be understood in terms of both economic and knowledge processes. With regard to the former, students are in this case responding to the growing material waste produced by an economic system in which the environmental cost of productive processes is generally unnoticed as an externality to the system. Through awareness-raising projects, students can help both consumers and producers to be more conscious of the choices they are making when using plastic bags in their purchases and discarding the byproducts of production that might otherwise be reused. From the perspec-

tive of knowledge processes, PSA students learning about the environment have increased the flow of knowledge in their community by raising the number of people who are generating knowledge about the local context and engaging in conversation with others about those topics. In that way, they are fostering empowerment by expanding the number of people involved in knowledge processes in their community. As PSA students, high school students and others learn the capabilities of generating knowledge and raising awareness, they can apply these to a growing number of issues they consider important to the development of the community. This corresponds to Lukes' (1974) second dimension of power, inviting more to join in knowledge processes.

Growing vegetable gardens in Kolwe. The experience of growing gardens in Kolwe was described in greater detail in the previous chapter, and will be revisited only briefly here as a third example of the types of community development fostered by the PSA program. In this case, students each grew their own vegetable gardens while also collaborating on a demonstration plot. They compared what they learned in the textbooks with what they were experiencing at home and on the demonstration plot. Drawing collectively from a number of experiences, as the sum of all their individual plots as well as the group plot, they were able to identify patterns and have deeper knowledge of what growing vegetables entailed. They also invited other members of the community to learn from their experiences, and asked local farmers about their practices. Through these exchanges, individuals sometimes tested one another's techniques.

From the perspective of community development as addressing the shortcomings of the political economy, this project allowed students to supplement their incomes and their diets by growing more vegetables. From the perspective of knowledge processes,

the endeavor provided a number of people with greater access to agricultural knowledge and the ability to choose between options and understand the reasoning behind different techniques. Furthermore, it enhanced the flow of knowledge in the community, helped to better recognize knowledge resources in the community, to appreciate more traditional knowledge, and to better navigate knowledge from different sources. In this case, then, empowerment related awareness building as well as involving more people in processes of generating knowledge.

In each of these three cases, while the content of the knowledge that was shared and generated helped participants to address particular aspects of their well-being that were not being addressed by capitalism, the more lasting impact to community development was a growth in the ability of members of the community to participate in knowledge processes, applying what they had learned, engaging in conversation with others about it, and generating relevant new knowledge through research and experience.

This emphasis on knowledge as key to development was critical to students' and tutors' vision of how they were contributing to their communities through their studies. For example, Jason, the graduate from the Kolwe group, considered it integral to what it meant to be a promoter of community well-being, which is how students and graduates are referred to in the program:

EL: So you mentioned before, 'promoter of community well-being,' what does that mean to be a promoter of community well-being?

J: I think it becomes like, it means you are now like an agent of change in the community. Yeah, you are there to help the community develop in one way or another, by putting in your efforts. Without depending on like, waiting for others to push you to do that. But you are there to initiate or bring about ideas, and help people to act in the community, where you are also involved. Not just telling them what to do, but being part and parcel of the projects that are taking on in the community. Yeah you are there to help where you can and also learn from other people, because it's not eve-

rything you know. You and the community both learn new ideas and try using them, then seeing what happens and learning from that. That's how the community advances.

Mapalo, the tutor, similarly explained:

So you find that we initiate conversations, we make friendships in the communities and I think these will be ongoing because we cannot say we developed the community, but we started a process which everyone has to embark on and see how we can develop the community, applying what we know and learn.

And Lucy, the graduate mentioned above described, in the context of the environmental club effort in Lubambe, having to clarify for others the vision of the PSA group:

And sometimes you find the teachers themselves coming directly and telling you, 'what can this project benefit our pupils?' 'Because we had pupils,' they would tell me like that, 'we had pupils in JADEs [a development project], we had pupils in anti-AIDS, now they are coming to this your project. What are you going, are you giving them t-shirts? what kinds of things, are you'--but we weren't giving them that, because what we did was, we are giving them access to knowledge that will not only sustain, but it's a knowledge that they'll share with other people. But then they wanted us to give them material things. But we were very creative in responding to them in a polite way, that even teachers did not feel offended, when we said, 'no we are giving them knowledge.' Even them they would be receptive to say, 'can you give us the same knowledge so that we look at that knowledge?'

The PSA program, she felt, was contributing to the community, and the high school students in general, through knowledge, not T-shirts.

Nonetheless, it is important to recognize that this picture of community development does not account for the role of money and material means, nor government, other institutions, and policy. Instead, it offers only a partial vision of what community development can look like, due to the limitations of the research mentioned above and the early stages of the program itself in the community. What stands out here, however, is the central role allocated to knowledge processes in community development, from the per-

spective of the PSA program, rather than technical solutions, monetary influx, or the provision of particular services, each of which tends to be more central in other approaches to community development. This is not to deny the importance of technology, money, services, and policy in supporting the flow of knowledge and the capacity to effectively use it.

Discussion

In this chapter, the PSA program is placed in the context of debates around knowledge and community development in international development. Closer examination of the case highlights questions that are important to consider in inquiries into science education for development. For example, relevant to any discussion of development is the question of how to reconcile the knowledge, values, and beliefs specific to a given community or region with those coming from outside of the community. Such discussions benefit from moving beyond casting these as binary opposites, instead recognizing the complexity with which individuals draw upon both, and the ways that knowledge, beliefs and values from different communities have always interacted and shaped one another. The case of the PSA program further highlights the importance of distinguishing between knowledge, values, and beliefs, and between science, technology, and values. While it is true these are intimately related, the above accounts suggest that strengthening the influence of science in a region need not imply the shift in values, beliefs, and technologies that is often suggested in this debate. That the scientific enterprise shares with Western culture certain values of rationality, analysis, etc, does not justify identifying science as a product of European and North American cultures, or even that they are

simply co-constructed social phenomena. Rather, there are certain values, attitudes, and patterns of thinking that form part of scientific work, and from among these, Western culture has tended to appreciate and emphasize certain of them to detriment of others. A given locality may benefit from boosts in science learning without putting in jeopardy their cultural foundations. Science education and globalization are not intrinsically two sides of the same coin. One might imagine, though, that the approach to science teaching affects the extent to which it can build from and enrich local ways of life. In this light, the PSA program in Zambia offers one example of an approach that seeks to develop endogenous science capacity in a manner coherent with local values and ways of life (Gitari, 2012).

One element of this approach in PSA, reflective of what many science educators have identified as key, is the space given to local knowledge, students' previous experiences, and relevant aspects of their culture and ways of life. As indicated above, there are many ways to approach such inclusion, and underlying each is a particular epistemological and political stance. While Aikenhead and Jegede (1999) have paid little attention to political implications, urging only that a bridge be built between science and traditional knowledge, Van Eijck and Roth (2008) have proposed a multiplicity that values both indigenous knowledge and science for their utility with minimal concern for their relationship to truth. It seems that their hope is that such an approach would foster more equitable consideration of the potentialities and resources of each culture. The PSA program breaks with the both approaches in its appreciation for local knowledge in the context of high regard for science, and in its concern for truth as something that reflects an external reality as accurately as possible. It is not uncommon, as seen in the example of these two

articles, for those approaches to science education, or development for that matter, that give considerable space for local knowledge, to minimize the value or possibility of truth as having some worthwhile connection to an external reality. This allows for the appreciation and inclusion of elements of local belief and practice that would tend to be at odds with the explanations of science. The consequence of this is a reticence to distinguish between different types of explanations of reality, for example the difference between a scientific account of a particular phenomenon and mythology regarding that phenomenon—both of which have merit and utility, but which ultimately serve different purposes. In PSA, knowledge processes pursue an increasingly accurate approximation of an external reality too complex to ever fully capture. Consideration of that external reality is present as one draws from science, local knowledge, and one's own experience. And in testing out different theories, techniques, and methods, one can perhaps achieve a closer read of that reality. At the same time, drawing from both local knowledge and science helps the question of values and worldview to be more explicitly detached from superficial renderings of science as a product of Western culture. Scientific values and approaches in local practice become more evident and those values often attributed to science but at odds with sustainability or other local values can also be more easily recognized and called into question. This broad rendering is not intended to superficially characterize science or local knowledge, but rather to highlight that when different perspectives are brought together to shine light on a single reality, the values and implicit assumptions that characterize one or the other can become easier to see.

Part of what allows local knowledge and science to come together in PSA in a manner not characterized by tension or trade-offs is the notion of a learning process.

Based on the assumption of an infinitely complex reality about which we can only make approximations, local knowledge and science both reflect efforts to describe that reality and identify patterns in it. Some parts of one may capture insights missing from the other; sometimes they may have complementary elements that reflect the same or similar understandings of reality, such as the case of polyculture and nitrogen-fixing. And sometimes one may have incorporated elements that do not describe reality very well at all. By means of a learning process, individuals and collectives can draw on different sources of knowledge in an effort to improve their practice and learn from experience. As they interact with reality on the basis of these explanations, they are able to weigh their suitability.

The example of PSA highlights an approach to development in which knowledge processes have taken center stage rather than economic processes. Rather than envision progress as dependent upon the ability to generate wealth and have that wealth benefit all members of society, progress in this case is seen to rely upon an ability to get to know an external reality better and better, to learn how knowledge of that reality can be utilized to improve individual and collective life, and to ensure that such knowledge flows through the community. Development is characterized as dependent upon the generation, application, and diffusion of knowledge, and justice is seen to require universal participation in these endeavors (Arbab, 2000). In comparison to criticisms of science and development that describe development as transplanting the tree of science from the North to the South (Escobar, 1994), this approach would seem to water the tree of science by building upon and nurturing the scientific tendencies and capacities that form part of human na-

ture—asking questions, trying to understand why, seeking patterns, manipulating conditions to better understand relationships, among other things.

Conclusion

There are a number of discussions in the literature that are key to conceptualizing how science education can contribute positively to community development. Among them are the question of the relationship between local knowledge and science, and the related question of the interplay of knowledge and power in development. While these topics are often discussed at a theoretical level, analyzing examples of particular approaches allows for consideration of both the theory and the practice. Any approach is based on particular political and epistemological assumptions. The PSA program draws upon both local knowledge and science in a manner that seeks to weigh insights from both against an external complex reality and allow understanding to progress in that light. The study of science in the program seeks to contribute to community development by building capacity to participate in the generation, application, and diffusion of knowledge. In that way, it implies an approach to development centered on knowledge processes, and watering local trees of science.

CHAPTER V

CONCLUSION

Science, local capacity for science, and science education have all been considered important elements of development efforts—by some. For others, these have been seen as elements of cultural oppression. Seeking to address this impasse, this paper has drawn on the experiences and theoretical position of single approach to science education for development as a means to engage and advance dialogue around two major issues. First, it sought to open up the black box of science education for community development. Articles and chapters that address the question of science education as a means of social transformation within the U.S. context often concentrate on issues of identity and voice in the science classroom (e.g. Basu, Calabrese Barton, Clairmont, & Locke; Calabrese Barton & Tan, 2010; Roth & Calabrese Barton, 2004), while those who do so in the global context of community development have often focused on recommendations at the level of theory (e.g. Gitari, 2012; Kyle, 1999; Savage & Naidoo, 2003). Close attention to the case of the Preparation for Social Action program in Zambia offered an opportunity to examine a concrete example of the sort of science education for transformation envisioned by Kyle and Gitari, while revising the notion of critical science agency of Calabrese Barton and her colleagues to have greater implications for the everyday lives and decisions of students. In this way, the case of PSA generated further insights in response to the question, ‘how can science education contribute to community development?’ At the same time, the topic of science education for development requires attention to a

number of valid concerns, in particular the question of its relationship to local knowledge and culture. This was the second major issue addressed by the paper.

With regard to the first aim of the paper, PSA students were using the science they learned in the program to improve their practices in growing vegetables and crops, to modify their habits regarding waste, and to engage with others in conversation about agriculture, the environment, and health. Beyond this, some identified in themselves certain changes in their attitudes and approaches to other areas of activity, most notably the habit of asking questions and trying to figure out the reasons behind things. At the same time, they were sharing what they learned with others in the community. Capacity to act, then, grew as a result of their science study in a few dimensions particularly relevant to social transformation: in their capacity to apply learning to practice, to draw from and contribute to flows of knowledge, and to generate knowledge about the local context. Such changes were rooted in a particular set of conceptions, meaning, and values that characterized the community of practice. Among these was an orientation to knowledge that encouraged exploring ideas for oneself and seeking input from multiple sources, and that framed the pursuit of knowledge as the effort to gain increasing, but never complete, insight into reality. The understanding and values of the figured world of PSA had important implications for students' science agency, as most students described sharing knowledge in a manner that respected the knowledge and reasoning of the listener, many recounted applying learning to practice in a manner that drew upon and sought to reconcile ideas from diverse sources, and some described experimenting and generating insights from their own experiences.

In this way, the qualitative look at the perceptions and experiences of students and tutors in the PSA program provided an opportunity to examine the border of where the classroom meets processes of everyday life. This is a critical border for conceptualizing the purpose and implications of education, the types of things that should be studied, why and how. The construct of critical science agency provided a means of framing the study of science specifically for its contributions outside of the classroom, in a manner directed at social transformation through everyday actions, decisions, and behavior, rather than through identity and representation. The notion of a figured world, or attention to the cultural context of learning in general, enhanced ability to see the connection between the classroom and students' everyday lives. Students were not simply applying scientific techniques and information to relevant situations; having a particular vision of their own relationship to knowledge, their relationship to others, and others' relationship to knowledge shaped the ways that they utilized science in their lives and offered it to others.

In relation to the second aim, the case of the PSA program illustrated a vision of the study of science in a manner that neither minimized the value of search for truth and certainty nor disregarded the propensity for human error and limitations, that both esteemed in science its universalist character and sought out the diversity and context specificity of local knowledge and culture. In not conflating modern science and the set of local knowledge, beliefs and practices as two separate but equal systems of knowledge, it would seem that the PSA program actually reinforced for students the value of traditional practices, values and knowledge. In both their conceptualizations and their practice, students found need for science and local knowledge, without having to maintain them as

separate. Further, the example found in the PSA program suggested the possibility and the need to separate the scientific from a number of particular cultural values and technologies with which it has often been equated. While modern science has made possible a number of technologies ranging from insecticides to cell phones, strengthening scientific capacity in each part of the world does not imply the need or the intention of adoption of those technologies. Though science is premised upon the ability to analyze, separating portions of reality from one another, and to seek a certain level of objectivity and clarity of language, this does not mean that these approaches are to be similarly valued in all aspects of life or that the products of other approaches, such as local myths and traditional practices, are to be considered of less value.

With these thoughts in mind, we can now return to the questions of phronetic research identified by Flyvbjerg (2001).

Flyvbjerg's Questions

At the outset, this inquiry was framed in terms of Flyvbjerg's (2001) phronetic social science research, positioning itself as a contribution to the discourse on how science education may serve the aims of individual and collective progress and well-being. It is now possible to return to the guiding questions identified by Flyvbjerg: Where are we going? Who gains and who loses, by which mechanisms of power? Is this desirable? What should be done?

Where Are We Going?

Implied by Flyvbjerg's first question is the value that social science can and should influence the direction that human societies take in policy and practice. The question of where we are going in science education for development is key, because there is not currently consensus on the topic, neither in theory nor practice. Yet, the discourse hinges on the positions with regard to fundamental conceptions such as: What is development? What is an appropriate role for science in the progress of human societies? And, if science is considered important to all societies, how does this proceed in a manner that is respectful of human diversity in culture, beliefs, practice, and life conditions? This inquiry has interacted with several prevalent approaches in the literature and then examined the PSA program as a case example. From these, we might speak of a few potential responses to where we are going in science education for development:

(1) *Science in development through assimilation.* In this case, it is expected, implicitly or explicitly, that 'developing' nations will progress along a path quite similar to the one charted by 'developed countries,' erroneously grouping diverse human experience into two egregious categories (e.g. USAID, 2006). The systems that have guided Western development in the last couple centuries, including democracy, capitalism, and science are expected—in their current form and often according to superficial visions of what they entail—to facilitate the progress of others, once other nations choose to properly adopt them. For this view, attention in theory and practice should be directed at facilitating assimilation, primarily by extending the reach of science and science education as thoroughly as possible.

(2) *Science in development through border-crossing.* From this perspective, full adoption is not expected, instead those from ‘non-Western cultures’ have to be assisted to develop the skills that would allow them to maneuver between disparate worldviews in the different settings of their lives (Aikenhead & Jegede, 1999). In this case, science education needs to develop the insights and techniques that would allow students to more effectively cross those borders while maintaining their local identity. Hopefully, this would eventually lead to more diverse representation in the fields of science inquiry.

(3) *Science in development through an endogenous community of learners.* Here, the aim of science education is to have a growing number of members of the population using science for local development (Gitari, 2012; Kyle, 1999; Savage & Naidoo, 2003). Attention is directed both at the capacity to utilize science in the local context and to participate in its practice.

Then, of course, a fourth option is to avoid science education for development out of concern that it imposes a worldview external to a given population. The case of the PSA program in Zambia has allowed for concrete exploration of option number three. Accounts of the experiences of tutors and students in the program would seem to suggest a means of engaging science that avoids some of the concerns implicit in the other options. The case study seems to be encouraging of continuing to learn about the implications of approaches to science education in development aiming to build an endogenous community of believers.

Who Gains and Who Loses, by What Mechanisms of Power?

Implicit in this second question seems to be the value that social science research help point us in directions in which more and more people gain, until ultimately, if possible, everyone gains and no one loses. Such a brief look at the PSA program in Zambia, exclusively from the perspective of those participating in the program makes it difficult to answer with certainty the question of who gains and who loses in this approach. Nonetheless, the program seems to be extending the reach of those who gain—both from the content of science and from the values and orientation of the program, which offers a vision of how science and local knowledge might both serve collective good. We can think of who gains in the PSA program in terms of a set of concentric circles. At the center, are the tutors of the program, who potentially gain the most. In studying the materials two or three times in the course of preparing and tutoring, they become most familiar with the scientific content and the program's orientation to knowledge. Indeed, in this study, they were more commonly applying the science they learned to complex and ongoing activities, and more often provided responses to questions that suggested more complexity in thinking about these ideas. Furthermore, the tutors already have a means by which they are using what they have learned to contribute to the well-being of the community, through the very act of tutoring. In the second circle are the students of the program, who find in the program the potential to develop in all the ways outlined in this paper. In the third circle lie members of the community with whom the students interact over an extended period of time, farmers they visit repeatedly, members of the environmental clubs, family members, among others. These individuals have access to some of the same concepts, information, techniques, and fundamental conceptions that PSA stu-

dents do, though often it is limited to one specific topic, for example farming or the environment. Finally, neighbors and others with whom students interact sporadically, or who hear ideas via others, benefit from the program, perhaps most commonly in relation to specific points or ideas.

From the research in this case, which as mentioned was only undertaken with participants in the program, there do not seem to be individuals who lose—who have less as a result of the program. There were, however, students who were disappointed that the program did not meet their financial aspirations, as they had hoped that study in the program would lead directly to employment with Inshindo.

Is This Desirable? What Should Be Done?

The question, ‘is this desirable?’ need not imply a yes-or-no position on a particular approach. Rather, this analysis of the PSA program is offered as one contribution to an ongoing conversation regarding the potential of science education for development. The study set out to examine a single case with particular promise for advancing the conversation on science education for development, and it would indeed seem that there are a number of desirable elements of the program that would be useful for others to draw upon. And more importantly, the example of PSA aided in identifying helpful ways of framing the conversation around science education and development. What should be done from here is to continue the process of sharing, applying and generating knowledge around the role of science education in development.

REFERENCES

- Abercrombie, N., Hill, S., & Turner, B. S. (1986). *Sovereign individuals of capitalism*. New York: Taylor & Francis.
- Arce, A. & Fischer, E. (2007). Creating natural knowledge: Agriculture, science, and experiments. In P. Sillitoe (Ed.), *Local science vs. global science: Approaches to indigenous knowledge in international development* (pp. 175 – 190). New York: Berghahn Books.
- Agrawal, A. (1995). Dismantling the divide between indigenous knowledge and scientific knowledge. *Development and change*, 26, 413-439.
- Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education*, 27, 1-52.
- Aikenhead, G. S. (2006). *Science education for everyday life: Evidence-based practice*. New York: Teachers College Press.
- Aikenhead, G. S., Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of cultural phenomenon. *Journal of Research in Science Teaching*, 36(3), 269-287.
- Akatugba, A. H. & Wallace, J. (1999). Sociocultural influences on physics students' uses of proportional reasoning in a non-Western country. *Journal of Research in Science Teaching*, 36(3), 305-320.
- Allexaht-Snyder, M., & Hart, L. E. (2001). "Mathematics for all": How do we get there? *Theory into Practice*, 40(2), 93-101.
- Alvares, C. (1992). Science. In Sachs (Ed.) *The development dictionary: A guide to knowledge as power* (pp. 243 - 249). New York: Zed Books.
- Arbab, F. (2000). Promoting a discourse on science, religion, and development. In S. Harper (Ed.) *The lab, the temple, and the market* (pp. 149-238). Ottawa, ON, Canada: International Development Research Centre.
- Arbab, F., Correa, G., & de Valcarcel, F. (1988). *FUNDAEC: Its principles and its activities*. Cali: CELATER.
- Asabere-Ameyaw, A., Dei, G. J. S., & Raheem, K. (2012). The question of indigenous science and science education: A look at the current literature. In A. Asabere-Ameyaw et al. (Eds.) *Contemporary issues in African sciences and science education* (pp. 15-28). The Netherlands: Sense Publishers.

- Bamiro, O. A. (2007). A framework for the strategic design of science and technology policy for African development. *African Development Review*, 19(1) 217-255.
- Ball, A., & Heath, S. B. (1993). Dances of identity: Finding an ethnic self in the arts. In S. B. Heath & M. W. McLaughlin, (Eds). *Identity and inner-city youth* (pp. 69-93). New York: Teachers College Press.
- Banda, D. (2008). *Education for all (EFA) and the 'African indigenous knowledge systems (AIKS)': The case of the Chewa people of Zambia*. Unpublished doctoral thesis, University of Nottingham, Nottingham, United Kingdom.
- Barnes, B. & MacKenzie, D. (1979). On the role of interests in scientific change. In R. Wallis (Ed.) *On the margins of science*. Sociological Review Monograph no. 27. Keele, Staffordshire: University of Keele.
- Basu, S. J. (2008). Powerful learners and critical agents: The goals of five urban Caribbean youth in a conceptual physics classroom. *Science Education*, 92, 252-277.
- Basu, S. J., Calabrese Barton, A., Clairmont, N., & Locke, D. (2009). Developing a framework for critical science agency through case study in a conceptual physics context. *Cultural Studies of Science Education*, 4, 345-371.
- Baxter Magolda, M. B. (1992). *Knowing and reasoning in college: Gender-related patterns in students' intellectual development*. San Francisco: Jossey-Bass.
- Belenky, M. F., Clinchy, B. M., Goldberger, N. R. & Tarule, J. M. (1986). *Women's ways of knowing: The development of self, voice and mind*. New York: Basic Books.
- Bernal, M. (1987). *Black Athena: The fabrication of ancient Greece, 1785-1985*. New Brunswick, NJ: Rutgers University Press.
- Bernstein, R. J. (1983). *Beyond objectivism and relativism: Science, hermeneutics, and praxis*. Philadelphia, PA: University of Pennsylvania Press.
- Blaikie, P., Brown, K., Stocking, M., Tang, L., Dixon, P., & Sillitoe, P. (1997). Knowledge in action: Local knowledge as a development resource and barriers to its incorporation in natural resource research and development. *Agricultural Systems*, 55, 2, 217 – 237.
- Boaler, J. & Greeno, J. G. (2000). Identity, agency, and knowing in mathematics worlds. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning*, (pp. 171-200). Westport, CT: Ablex Publishing.
- Bohm, D. (1981). *Wholeness and the implicate order*. London: Routledge and Kegan Paul.
- Bourdieu, P. (1977). *Outline of a theory of practice*. Cambridge: Cambridge University Press.

- The Blacksmith Institute (2007). Annual Report 2007. New York: The Blacksmith Institute.
- Brickhouse, N. W. & Lowery, P. (2000). What kind of a girl does science? The construction of school science identifies. *Journal of Research in Science Teaching*, 37, 441-458.
- Briggs, J. (2005). The use of indigenous knowledge in development: Problems and challenges. *Progress in Development Studies*, 5(2), 99-114.
- Calabrese Barton, A. (2003). *Teaching science for social justice*. New York: Teachers College Press.
- Calabrese Barton, A. & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. *The Journal of the Learning Sciences*, 19(2), 187-229.
- Campfens, H. (1997). *Community development around the world: Practice, theory, research, and training*. Toronto: University of Toronto Press.
- Carspecken, P. F. (1996). *Critical ethnography in educational research: A theoretical and practical guide*. London: Routledge.
- Chalmers, A. F. (1976). *What is this thing called science: An assessment of the nature and status of science and its methods*. Queensland, Australia: Queensland University Press.
- Chitambala, C. (2013). *Factors affecting HIV counselling and testing (HCT) in the provision of prevention of mother to child transmission (PMTCT) services among pregnant women in Kabwe, Central province of Zambia*. Unpublished master's thesis, Stellenbosch University, Stellenbosch, South Africa.
- Cleveland, D. A. & Soleri, D. (2007). Farmer knowledge and scientist knowledge in sustainable agricultural development: Ontology, epistemology and praxis. In P. Sillitoe (Ed.), *Local science vs. global science: Approaches to indigenous knowledge in international development* (pp. 209 – 230). New York: Berghahn Books.
- Colson, E. (1999). The Bantu Botatwe: Changing political definitions in Southern Zambia. In D. Parkin (Ed.), *The politics of cultural performance*. Oxford: OUP.
- Daly, H. E. & Cobb, J. B. (1994). *For the common good: Redirecting the economy toward community, the environment, and a sustainable future*. Boston, MA: Bacon Press.
- DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, 37, 582-601.

- DeFilippis, J. & Saegert, S. (2013). Communities develop: The question is, how? In J. DeFilippis & S. Saegert (Eds.) *The community development reader, 2nd edition* (pp. 1 – 8). New York: Routledge.
- Dei, G. J. S. (2003). Sustainable development in the African context: Revisiting some theoretical and methodological issues. *African Development, 18*, 97-110.
- Diamond, J. M. (1997). *Guns, germs, and steel: The fate of human societies*. New York: W. W. Norton & Company, Inc.
- diSessa, A. A. (2006). A history of conceptual change research: Threads and fault lines. In Sawyer, R. K. (Ed.) *The Cambridge handbook of the learning sciences* (pp. 265-282). Cambridge: Cambridge University Press.
- Dlodlo, T. S. (1999). Science nomenclature in Africa: Physics in Nguni. *Journal of Research in Science Teaching, 36*(3), 321-331.
- Dos Santos, W. L. P. (2008). Scientific literacy: A Freirean perspective as a radical view of humanistic science education. *Science Education, 93*(2), 361-382.
- Dove, M. R., Smith, D. S., Campos, M. T., Mathews, A. S., Rademacher, A., Rhee, S., & Yoder, L. M. (2007). Globalization and the Construction of Western and Non-Western Knowledge. . In P. Sillitoe (Ed.), *Local science vs. global science: Approaches to indigenous knowledge in international development* (pp. 130 – 154). New York: Berghahn Books.
- Dzama, E. N. N. & Osborne, J. F. (1999). Poor performance in science among African students: An alternative explanation to the African worldview thesis. *Journal of Research in Science Teaching, 36*(3), 387-405.
- Ellen, R. (2007). Local and scientific understandings of forest diversity on Seram, Eastern Indonesia. In P. Sillitoe (Ed.), *Local science vs. global science: Approaches to indigenous knowledge in international development* (pp. 41 – 74). New York: Berghahn Books.
- Ellen, R. & Harris, H. (2000). Introduction. In Ellen, R., Parker, P. and Bicker, A. (Eds.). *Indigenous environmental knowledge and its transformations* (pp. 1 – 33). Amsterdam: Harwood Academic Publishers.
- Escobar, A. (1994). *Encountering development: The making and unmaking of the Third World*. Princeton, NJ: Princeton University Press.
- Esteva, G. (1992). Development. In W. Sachs (Ed.) *The development dictionary: A guide to knowledge as power* (pp. 1 – 23). New York: Zed Books.
- Evans, S. & Prilleltensky, I. (2007). Youth and democracy: Participation for personal, relational, and collective well-being. *Journal of Community Psychology, 35*(6), 681 – 692.

- Examinations Council of Zambia. (2014). Senior Secondary (G12). Available at http://www.exams-council.org.zm/?page_id=1369. Accessed on 8.20.2014.
- Ferguson, J. (1997). Development and bureaucratic power in Lesotho. In R. Rahnema with V. Bawtree (Eds.) *The post-development reader* (pp. 223 – 233). New York: Zed Books.
- Ferguson, J. (1999). *Expectations of modernity: Myths and meanings of urban life on the Zambian Copperbelt*. Berkeley, CA: University of California Press.
- Ferguson, J. (2006). *Global shadows: Africa in the neoliberal world order*. Durham, N.C.: Duke University Press.
- Freire, P. (1970). *Pedagogy of the Oppressed*. New York: Continuum.
- Flyvbjerg, B. (2001). *Making social science matter: Why social inquiry fails and how it can succeed again*. Cambridge: Cambridge University Press.
- Foucault, M. (1977). *Discipline and punishment*. London: Allen Lane.
- Foucault, M. (1979). *The history of sexuality: Part 1*. London: Allen Lane.
- FUNDAEC. (1999). *Constructing a conceptual framework for social action*. Cali, Colombia: Fundación para la Aplicación de la Ciencias (FUNDAEC).
- FUNDAEC. (2005a). *Food production on small farms. Unit 1: Planting crops*. Cali, Colombia: Fundación para la Aplicación de la Ciencias (FUNDAEC).
- FUNDAEC. (2005b). *Matter. Unit 1: The heating and cooling of matter*. Cali, Colombia: Fundación para la Aplicación de la Ciencias (FUNDAEC).
- FUNDAEC. (2006). *Education for Development*. Internal document. Cali, Colombia: Fundación para la Aplicación de la Ciencias (FUNDAEC).
- FUNDAEC. (2010). *Family Health. Unit 1: Health and disease*. Cali, Colombia: Fundación para la Aplicación de la Ciencias (FUNDAEC).
- Galeano, E. (1997). To be like them. In R. Rahnema with V. Bawtree (Eds.) *The post-development reader* (pp. 214 – 222). New York: Zed Books.
- Garrett, M. J. & Granqvist, C. G. (1998). *Basic sciences and development: Rethinking donor policy*. Aldershot, England: Ashgate.
- Gaventa, J. & Cornwall, A. (2006). Power and knowledge. In P. Reason & H. Bradbury (Eds.) *Handbook of action research* (pp. 71 – 82). London: Sage Publications.
- Gee, J. P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education*, 25, 99-125.

- George, S. (1997). How the poor develop the rich. In R. Rahnema with V. Bawtree (Eds.) *The post-development reader* (pp. 207 – 213). New York: Zed Books.
- Giddens, A. (1979). *Central problems in social theory: Action, structure, and contradiction in social analysis*. Los Angeles, CA: University of California Press.
- Gilbert, S. F. (1988). Cellular politics: Ernest Everett Just, Richard B. Goldschmidt and the attempt to reconcile embryology and genetics. In R. Rainger and J. Maienschein (Eds.) *The American development of biology* (pp. 311 – 346). Philadelphia, PA: University of Pennsylvania Press.
- Gilligan, C. (1982). *In a different voice: Psychological theory and women's development*. Cambridge, MA: Harvard University Press.
- Gitari, W. (2012). Engaging scientific activities to build endogenous science and lay foundation for the improvement of living conditions in Africa. In A. Asabere-Ameyya et al. (Eds.) *Contemporary issues in African sciences and science education* (pp. 29 – 54). The Netherlands: Sense Publishers.
- Gray, B. V. (1999). Guest editorial: Science education in the developing world: Issues and considerations. *Journal of Research in Science Teaching*, 36(3), 261-268.
- Haambokoma, C. (2007). Nature and causes of learning difficulties in genetics at high school level in Zambia. *Journal of International Development and Cooperation*, 13(1), 1-9.
- Haraway, D. (1989). *Primate visions: Gender, race, and nature in the world of modern science*. New York: Routledge.
- Harding, S. (2008). *Sciences from below: Feminisms, postcolonialities, and modernities*. Durham, NC: Duke University Press.
- Harding, S. (1998). *Is science multicultural?: Postcolonialisms, feminisms, and epistemologies*. Indiana: Indiana University Press.
- Hayward, C. R. (1998). De-facing power. *Polity*, 31(1), 1-22.
- Hess, D. (1995). *Science and technology in a multicultural world: The cultural politics of facts and artifacts*. New York: Columbia University Press.
- Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, 67(1), 88-140.
- Holland, D., Skinner, D., Lachicotte, W., & Cain, C. (1998). *Identity and agency in cultural worlds*. Cambridge, MA: Harvard University Press.

- Honeyman, C. (2010). Social responsibility and community development: Lessons from the Sistema de Aprendizaje Tutorial in Honduras. *International Journal of Educational Development*, 30, 599-613.
- Illich, I. (1997). Development as planned poverty. In Rahnema & Bawtree (Eds.) *The post-development reader* (pp. 94 – 102). London: Zed Books.
- Indge, W. J. E. (1976). The potential for local manufacture of school science equipment and related problems. Report of a Commonwealth Regional Seminar Workshop, Nassau, Bahamas, Nov. 1976. 26-30.
- Janzen, M. D. (2008). The women of agabaya: Education and post-development theory. *Canadian Journal of Education*, 31(1), 8 – 31.
- Jegede, O. J. (1997). School science and the development of scientific culture: A review of contemporary science education in Africa, *International Journal of Science Education*, 19(1), 1-20.
- Jegede, O. J. (1999). Science education in nonwestern cultures: Towards a theory of collateral learning. In L. M. Semali & J. L. Kincheloe (Eds.). *What is indigenous knowledge? Voices from the Academy* (pp. 119 – 143). New York: Falmer Press.
- Jensen, P. & Nielsen, H. S. (1997). Child labour or school attendance? Evidence from Zambia. *Journal of Population Economics*, 10(4), 407-424.
- Kalamananthan, K. (1970). An investigation into problems involved in science teaching in secondary schools in the six northern states of Nigeria. *Journal of Science Teachers Association of Nigeria*, 10(3), 60-62.
- Kelly, G. J., McDonald, S., & Wickman, P. (2012). Science learning and epistemology. In B.J. Fraser, K. Tobin, C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 281 – 291). New York: Springer.
- Kenny, C., & Sumner, A. (2011). How 28 countries escaped the poverty trap. *The Guardian, poverty matters blog*. Available at <http://www.theguardian.com/global-development/poverty-matters/2011/jul/12/world-bank-reclassifies-28-poor-countries>. Accessed 8.20.14.
- Kieft, G. (2009). *Interaction between school and community in the localized curriculum: The case of primary schools in Mumba and Monze district, Zambia*. Unpublished doctoral dissertation, Wageningen University, Wageningen, Netherlands.
- King, P. M. & Kitchener, K. S. (1994). *Developing reflective judgment: Understanding and promoting intellectual growth and critical thinking in adolescents and adults*. San Francisco: Jossey-Bass.
- Knorr-Cetina, K. (1999). *Epistemic cultures: How the sciences make knowledge*. Cambridge, MA: Harvard University Press.

- Kohlberg, L. (1969). Stage and sequence: The cognitive-development approach to socialization. In D. A. Goslin (Ed.), *Handbook of socialization theory and research*. Chicago: Rand McNally.
- Kuhn, T. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.
- Kyle, W. C., Jr. (1999). Science education in developing countries: Challenging first world hegemony in a global context, *Journal of Research in Science Teaching*, 36(3), 255-250.
- Lakatos, I. (1970). *The methodology of scientific research programmes*. Cambridge: Cambridge University Press.
- Latouche, S. (1997). Paradoxical growth. In R. Rahnema with V. Bawtree (Eds.) *The post-development reader* (pp. 135 – 142). New York: Zed Books.
- Latour, B. (1987). *Science in action: How to follow scientists and engineers through society*. Cambridge, MA: Harvard University Press.
- Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
- Leach, M., Scoones, I., & Wynne, B. (2005). *Science and citizens: Globalization and the challenge of engagement*. New York: Zed Books.
- Lee, Y. J. (2011). Identity-based research in science education. In B. J. Fraser & K. Tobin (Eds.) *Second international handbook of science education*. London: Springer.
- Lehrer, R. & Schauble, L. (2006). Cultivating model-based reasoning in science education. In Sawyer, R. K. (Ed.) *The Cambridge handbook of the learning sciences* (pp. 371 – 388). Cambridge: Cambridge University Press.
- Lidar, M., Ludqvist, E., & Ostman, L. (2005). Teaching and learning in the science classroom: The interplay between teachers' epistemological moves and students' practical epistemology. *Science Education*, 90, 148-163.
- Longino, H. & Doell, R. (1996). Body, bias, and behaviour: A comparative analysis of reasoning in two areas of biological science. In E. F. Keller and H. E. Longino (Eds.) *Feminism and science* (pp. 73 – 90). Oxford: Oxford University Press.
- Lukes, S. (1974). *Power: A radical view*. London: Macmillan.
- Lyotard, J. F. (1984). *The postmodern condition: A report on knowledge*. Minneapolis, MN: University of Minnesota Press.
- Majgaard, K. & Mingat, A. (2012). *Education in Sub-Saharan Africa: A comparative analysis*. Washington, D. C.: The World Bank.

- Martin, E. (1991). The egg and the sperm: How science has constructed a romance based on stereotypical male and female roles. *Signs*, 16(3), 485-501.
- Maton, K. (2008). Empowering community settings: Agents of individual development, community betterment and positive social change. *American Journal of Community Psychology*, 41, 4-21.
- Ministry of Education. (2005). *Guidelines for the development of the localized curriculum in Zambia Basic Education*. Lusaka: Curriculum Development Centre.
- Moll, L. C., Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory into Practice*, 31(2), 132-141.
- Morin-Labatut, G., and Akhtar, S. (1992). Traditional environmental knowledge: a resource to manage and share. *Development*, 4, 24-29.
- Monahan, T. (2005). *Globalization, technological change, and public education*. New York: Taylor & Francis.
- Motschilnig, R. (2001). *Indigenous knowledge and localized curriculum in Zambia: ...the road to sustainable development?* Germany: VDM.
- Mudenda, V. (2008). *Zambian grade twelve pupils' experiences of biology practical work during school certificate examinations: The case of Kabwe High School*. Unpublished master's thesis, University of Zambia, Lusaka, Zambia.
- Murphy-Graham, E. (2007). Promoting participation in public life through secondary education: Evidence from Honduras. *Prospect*, 37(1), 95-111.
- Murphy-Graham, E. (2010). And when she comes home? Education and women's empowerment in intimate relationships. *International Journal of Educational Development*, 30, 320-331.
- Murphy-Graham, E. & Lample, J. (2014). Learning to trust: Examining the connections between trust and capabilities friendly pedagogy through case studies from Honduras and Uganda. *International Journal of Educational Development*, 36, 51-62.
- Nasir, N. S. (2002). Identity, goals, and learning: Mathematics in cultural practice. *Mathematical Thinking and Learning*, 4(2-3), 213-247.
- Nasir, N. S., & Cooks, J. (2009). Becoming a hurdler: How learning settings afford identities. *Anthropology & Educated Quarterly*, 40(1), 41-61.
- Nasir, N. S. & Hand, V. (2008). From the court to the classroom: Opportunities for engagement, learning, and identity in basketball and classroom mathematics. *The Journal of the Learning Sciences*, 17(2), 143-179.

- Ndirangu, M., Kathuri, N. J., & Mungai, C. (2003). Improvisation as a strategy for providing science teaching resources: An experience from Kenya. *International Journal of Educational Development*, 23(1), 75-84.
- Ngubane, B. S. (2003). Prologue. In M. Savage and P. Naidoo. (Eds.) *Popularisation of science and technology: Some case studies from Africa*. Commonwealth Secretariat.
- Norman, O., Ault, Jr., C. R., Bentz, B., & Meskimen, L. (2001). The black-white “achievement gap” as a perennial challenge of urban science education: A sociocultural and historical overview with implications for research and practice. *Journal of Research in Science Teaching*, 38(10), 1101-1114.
- Nussbaum, M. C. (2000). *Women and human development: The capabilities approach*. New York: Cambridge University Press.
- Nygren, A. (1999). Local knowledge in the environment-development discourse: From dichotomies to situated knowledges. *Critique of Anthropology*, 19, 3, 267 – 288.
- Ogunniyi, M. B. (1986). Two decades of science education in Africa. *Science Education*, 70(2), 111-122.
- Ogunniyi, M. B. (1995). The development of science education in Botswana. *Science Education*, 79(1), 95-109.
- Ogunniyi, M. B. (1996). Science, technology and mathematics: The problem of developing critical human capital in Africa, *International Journal of Science Education*, 18(3), 267-284.
- Perry Jr., W. G. (1970). *Forms of intellectual and ethical development in the college years: A scheme*. San Francisco, CA: Jossey-Bass Publishers.
- Popper, K. R. (1959). *The logic of scientific discovery*. London: Hutchinson and Co.
- Rahnema, M. & Bawtree, V. (1997). *The post-development reader*. New York: Zed Books.
- Republic of Zambia Central Statistical Office. (2011). *2010 census of population and housing: Preliminary population figures*.
- Rist, G. (2002). *The history of development: From Western origins to global faith*. New York: Zed Books.
- Rogan, J. M., & Gray, B. V. (1999). Science education as South Africa’s Trojan house. *Journal of Research in Science Teaching*, 36(3), 373-385.
- Roth, W. M. & Calabrese Barton, A. (2004). *Rethinking scientific literacy*. New York: Routledge.

- Roth, W. M. & Lee, S. (2004). Science education as/for participation in the community. *Science Education*, 88, 263 – 291.
- Roth, W. M. & Tobin, K. (2007). Science, learning, identity: Sociocultural and cultural-historical perspectives (Vol. 7). Sense Publishers.
- Sachs, W. (1992). One world. In Sachs (Ed.) *The development dictionary: A guide to knowledge as power* (pp. 111-126). New York: Zed Books.
- Sachs, W. (1997). The need for the home perspective. In R. Rahnema with V. Bawtree (Eds.) *The post-development reader* (pp. 290-301). New York: Zed Books.
- Saegert, S. (2006). Building civic capacity in urban neighborhoods: An empirically grounded anatomy. *Journal of Urban Affairs*, 28(3), 275-294.
- Sardar, Z. (1989). *Explorations in Islamic science*. London: Mansell Publishing Limited.
- Savage, M. & Naidoo, P. (2003). *Popularisation of science and technology: Some case studies from Africa*. Commonwealth Secretariat.
- Sawyer, R. K. (2006). *The Cambridge handbook of the learning science*. Cambridge: Cambridge University Press.
- Sbert, J. M. (1992). Progress. In Sachs (Ed.) *The development dictionary: A guide to knowledge as power* (pp. 212 – 227). New York: Zed Books.
- Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology*, 82(3), 498-504.
- Sclove, R. (1995). *Democracy and technology*. New York: The Guilford Press.
- Semali, L. M. & Kincheloe, J. L. (2002). *What is indigenous knowledge? Voices from the academy*. New York: Routledge.
- Semken, S. & Freeman, C. B. (2008). Sense of place in the practice and assessment of place-based science teaching. *Science Education*, 92(6), 1042-1057.
- Sen, A. (1999). *Development as freedom*. London: Oxford University Press.
- Serpell, R. (1993). *The significance of schooling: Life-journeys in an African society*. Cambridge: Cambridge University Press.
- Sfard, A. & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Education & Educational Research*, 34(4), 14-22.
- Shiva, V. (1991). *The violence of the green revolution: Third world agriculture, ecology and politics*. New York: Zed Books.

- Shiva, V. (1997). Western science and its destruction of local knowledge. In R. Rahnema with V. Bawtree (Eds.) *The post-development reader* (pp. 161 – 167). New York: Zed Books.
- Shizha, E. & Abdi, A. A. (2005). Democratizing education in Zambia: Sociohistorical analyses. In A. A. Abdi & A. Cleghorn (Eds.) *Issues in African education: Sociological perspectives* (pp. 241-258). New York: Palgrave Macmillan.
- Shumba, O. (1999). Relationship between secondary science teachers' orientation to traditional culture and beliefs concerning science instructional ideology. *Journal of Research in Science Teaching*, 36(3), 333-355.
- Sillitoe, P. (2007). Local science vs. global science: An overview. In P. Sillitoe (Ed.), *Local science vs. global science: Approaches to indigenous knowledge in international development*. New York: Berghahn Books.
- Simmel, G. (1903). *The metropolis and mental life*.
- Snively, G. & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education*, 85, 1, 6-34.
- Stepan, N. L. (1996). Race and gender: The role of analogy in science. In E. F. Keller and H. E. Longino (Eds.) *Feminism and science* (pp. 121 – 136). Oxford: Oxford University Press.
- Tan, E. & Calabrese Barton, A. (2012). A narrative pedagogy for critical science literacy. In Tan, E. & Calabrese Barton, *Empowering science and mathematics education in urban schools* (pp. 51 – 76). Chicago: University of Chicago Press.
- Tan, E., Calabrese Barton, A., Turner, E. & Gutierrez, M. V. (2012). *Empowering science and mathematics education in urban schools*. Chicago: The University of Chicago Press.
- Teibo, B. O. (1975). An investigation into the problems encountered by Nigerian Secondary School pupils in learning chemistry. *Journal of Science Teachers' Association of Nigeria*, 13(3), 71-76.
- Tilley, H. (2011). *Africa as a living laboratory: Empire, development, and the problem of scientific knowledge, 1870 – 1950*. Chicago: University of Chicago Press.
- Tindall, T. & Hamil, B. (2004). Gender disparity in science education: The causes, consequences, and solutions. *Education*, 125(2), 282-295.
- Tonnies, F., & Loomis, C. P. (1957). *Community and society*. New York: Courier Corporation.
- Traweek, S. (1988). *Beantimes and lifetimes: The world of high energy physicists*. Cambridge, MA: Harvard University Press.

- Turner, E. (2012). Critical mathematical agency in the overcrowding at Francis Middle School Project. In Tan, E. & Calabrese Barton, *Empowering science and mathematics education in urban schools* (pp. 51-76). Chicago: The University of Chicago Press.
- UN Millennium Project (2005). *Innovation: Applying knowledge in development*. Task Force on Science, Technology, and Innovation.
- UNESCO (1983). *Science and technology education and national development*. Paris: UNESCO.
- UNESCO Institute for Statistics. (2014). Zambia: County profile. Available at <http://www.uis.unesco.org/DataCentre/Pages/country-profile.aspx?code=ZMB®ioncode=40540>. Retrieved 8.20.2014.
- Urry, C. M. (2008). Are photons gendered? Women in physics and astronomy. In L. Schiebinger (Ed.) *Gendered innovations in science and engineering*. Stanford, CA: Stanford University Press.
- USAID. (2006). *The fundamental role of science and technology in international development*. Committee on Science and Technology in Foreign Assistance. Washington, DC: The National Academies Press.
- Van Eijck, M. & Roth, W. M. (2007). Keeping the local local: Recalibrating the status of science and traditional ecological knowledge in education. *Science Education*, 91, 6, 926-947.
- Waldrip, B. G. & Taylor, P. C. (1999). Permeability of students' worldviews to their school views in a non-Western developing country. *Journal of Research in Science Teaching*, 36(3), 289-302.
- Weber, M. (1978). *Economy and society*. Berkeley, CA: University of California Press.
- Wenger, J. (1999). *Communities of practice: Learning, meaning, and identity*. New York: Cambridge University Press.
- Westheimer, J. & Kahne, J. (2004). What Kind of Citizen? The Politics of Educating for Democracy. *American Educational Research Journal*, 41, 237-269.
- World Food Programme. (2014). Zambia: Overview. Available at <https://www.wfp.org/countries/zambia/overview>. Accessed 8.20.14.
- Yoloye, E. A., & Bajah, S. T. (1981). *Science Education Programme for Africa, Vol. 1. A report of twenty years of science education in Africa*. Ibadan, Nigeria.
- Yoshinori, I., Nakayama, S., Muzandu, K., Choongo, K., Teraoka, H., Mizuno, N., & Ishizuka, M. (2010). Heavy metal contamination of soil and sediment in Zambia. *African Journal of Environmental Science and Technology*, 4(11), 729-739.

Zaoual, H. (1997). The economy and symbolic sites of Africa. In M. Rahema & V. Bawtree (Eds.) *The post-development reader*. New York: Zed Books.

Zymelman, M. (1990). *Science, education, and development in Sub-Saharan Africa*. Washington, D.C.: The World Bank.