18 Language Socialization in Art and Science

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Introduction

With the exception of mathematics, which relies on numeral and other symbol systems and thus needs verbal explication for initiates, scientific and artistic activities have throughout history depended primarily on the capacity of the human species to observe, experiment, imagine, and explore. From infancy through the life course, individuals undertake initiatives aesthetic in their design and delivery and reflective of the need of humans to know their natural surroundings, to figure out how things work, and to discover what lies beyond the immediate horizon. In this chapter I argue that across societies, outside of formal education settings, language plays a relatively minor role in children's socialization into art and science. Other human resources – visual, gestural, olfactory, and tactile – precede, override, or complement the linguistic throughout the early years as the young prepare to advance their skills and knowledge in science and art.

Definitions of art and science differ significantly across societies. Some languages have no general term that refers to either art or science. In this chapter, 'art' refers to any purposefully created form of representation to which its creators assign an aesthetic and communicative valuation. 'Art' includes painting, drawing, and other visual arts; sculpture; oral and written literature; dance; music (including instrument creation); video films and still photographs; architecture; and garden development. All these forms have some permanence, but 'art' may also refer to temporary forms of creation, such as ice sculpture, presentation of food, and sand painting. 'Science' is taken to be the conceptualization of systems of process and categorization in the physical and natural world for which science-makers believe an objective reality exists. Across societies, art and science carry

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close relationships with cosmology, religion, and beliefs about human origin and destiny.

This chapter suggests that a human universal in early learning of science and art is reliance on seeing and doing and that verbal instruction and explication have come only in recent centuries to be essential complements to vision and action for older learners being socialized into art and science. Briefly considered here are historical perspectives on the inextricable ties between art and science across the ages and how this bond is facilitated by visuospatial and motor capacities. A review of socialization patterns surrounding science and art for children in several indigenous settings follows. Here formal schooling has a limited relationship to identity development and future economic potential for the young. Finally, we examine language forms that advance knowledge and skills of art and science in planned learning environments – school-oriented homes, classrooms, studios, rehearsal zones, and laboratories.

The Unity of Art and Science: A Historical Perspective

From the time that humans invented tools and created drawings on cave walls, art and science have been interdependent. Both played essential roles in the evolving complexity of social groups (Deacon 1997, 2006; Donald 1991, 2001, 2006). Early governments relied on artists and scientists to design and invent technologies that made architectural monuments possible and enabled dynasties to record their histories, calendrical cycles, and astronomical and meterological anomalies. Architects of city walls, temples, and state buildings of the ancient kingdoms of Africa, the Middle East, and Latin America worked as artist scientists or as scientist artists. The aesthetic and wondrous were inseparable from the pragmatic and analytical.

The evolutionary course of biological functions and social needs brought to human consciousness a sense of inquiry and aesthetic sensibility beyond immediate survival needs. Humans learned to explore the world visually, searching out degrees of similarity and difference in details of space, color, form, and motion. By the Middle Ages, arenas of knowledge to which we now give names such as astronomy, botany, climatology, geology, physics, physiology, and zoology emerged. Between the Medieval period and the eighteenth century, visual representation of newly discovered species, processes, and systems travelled around the world in diagrams, navigational charts, models, sketches, and paintings (Bender and Marrinan 2010). As special interests in science developed, art forms represented these in surgical theatres, architectural monuments, dramatic portrayals, and illustrated books. Verbal supports through nomenclature, taxonomies, map legends, and other classification systems of science increased in length and complexity as formal instruction in art and science developed. European philosophers and statesmen expressed art and science as a one-breath phrase. The earliest surgeries took place in theatres; around the world, the planetarium doubled as

hall of science and architectural monument. From the fifteenth century, when artists came to be known as individuals, they relied on science in their development of color, perspective, and constructions of space and image. Leonardo da Vinci (1452–1519), Johannes Vermeer (1632–1675), and Carl Linnaeus (1707–1778) saw no distinction between art and science.

In the Western world, as formal education became possible for those beyond the most privileged, separate arenas of study developed for art and science. The Enlightenment pulled the two apart into distinct disciplines within higher education, foreshadowing art museums and science centers as entirely separate entities. The distinct and increasingly distanced professional identities of 'scientist' and 'artist' came about (Kemp 1990; Stafford 1994). Each splintered into subfields with extensive naming and explaining. This division paralleled the split of seeing as a modality from other senses. This shift is noted as a time when 'seeing produces as its cultural endpoint a unified visual and ideological field' (Wolf 2001: 11). 'Art' came to mean literature, visual illustration, music, sculpture, architecture, dance, film, and dramatic performance. Each of these developed its own subdivisions that different cultural groups, formal education institutions, and governmental agencies continued to rank order and to target for specific social and economic classes. 'Science' created and erased subfields, relying on technology to encompass what had in previous eras been merely the 'art' within science. Model-building, graphic design, charting and mapping, along with interpretation of electronic images, came to live almost entirely within departments of science and technology. Professional applied fields of science, such as medicine, oceanography, astrophysics, and biomedical engineering, brought new technologies of sight and sound firmly into the realm of the 'scientific' – no longer to be viewed as 'artistic.'

Curiously, art and science have remained linked in forms of entertainment. In eighteenth-century European society, optical cabinets, illustrations in children's books and popular literature, architectural models, machines that provoked amusement and marvel, and often outrageous displays of artifacts collected by explorers of distant cultures and regions of the globe came to be viewed as means to educate and entertain children. The leisure industry that developed during the eighteenth century brought children and adults together in various forms of entertainment that depended on visual as well as verbal dimensions of 'artful science' and the 'science of art' (Kemp 1990; Stafford 1994). Since that time, the two have remained bonded through developments of science fiction, animation, graphic design, and video games, and in websites and kits for building robots and developing home-based artful science enterprises (Stafford 2007).

Neuroscience's Contributions to Language Socialization Research

Neuroscience researchers, using functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG) technologies, provide insights into the role of visualization in development of fluency with complex language, especially that

related to science (Ramadas 2009). Reading and interpreting visual images, such as maps, graphs, charts, and photographs, coordinate with verbal reasoning (Berger, Roloff, and Roskos-Ewoldsen 2009; Suwa and Tversky 1997). Visuospatial thinking accelerates inquiry around concepts and enables transfer of mental images into verbal forms. Visuospatial thinking also works as mnemonic for verbal material and as aid to reasoning with mental models (Kosslyn, Ganis, and Thompson 2006; Schnotz 2002; Uttal and O'Doherty 2008).

Neuroscientists explicate the high overlap in neural networks between language comprehension and visual perception of details in images. This work adds support to the importance of bringing image, word, and action together in learning environments of children (Hari and Kujala 2009). Critical to understanding children's reading of written language is the linkage between visual imagery and the motor system during reading (Pfeifer and Bongard 2006; Speer et al. 2009). Thus, if readers already know about or have experienced motor actions represented in what they read, their brains reflect motor neuronal activity. In other words, readers 'embody' or simulate through motor neuronal activity what is described in the words they read. Knowledge of how language learning works in relation to conscious imagery changes as neuroscientists understand more about neural representations of modalities of simulation, situated action, and bodily states in the brain (Barsalou 2008; Meltzoff et al. 2009).

Theories of grounded cognition emphasize the role of 'mirror neurons' on the contingent motor practice that results from seeing another person perform an action (Meltzoff and Prinz 2002; Rizzolatti and Craighero 2004). Behavioral scientists have long studied the circuit of joint attention or intersubjectivity of adult and infant simultaneously viewing and manipulating an object and the infant 'checking in' on the eye gaze of the adult during imitative behavior (Brown, this volume; Finnegan 2002: Kulick 1992; Rogoff 2003; Schieffelin 1990). Neuroscientists have expanded our understanding of the creative potential of this imitative behavior by pointing out how humans, unlike other higher-order primates, do not merely imitate – they adapt and create. The capacity of humans to take the perspective of the other and to collaborate in jointly enacted scenes appears to be critical to the effectiveness with which humans move beyond imitation to creativity (Meltzoff 2005).

Children observe caregivers, perform to draw their attention, and explore new objects in their environments by checking in visually with caregivers. This ability to pay attention to self and other in the perception and exploration of an object develops in the first year of life and appears to be intimately tied to infants' fundamental social nature and their ability to pick up on the communicative intentions of others (Kuhl 2007). The sensitivity of the young to joint visual attention and their ability to imitate and extend (often through improvisation) the actions of elders is critical to language learning (Bruner 1983). The 'double exposure' of learner looking, expert looking, and both perceiving the scene or action as a model for memory toward subsequent action coalesce to instill a sense of reciprocity integral to the intersubjectivity upon which relations for learning build (Heath 2000, forthcoming). Such learning is critical to the work of artists and scientists across societies and institutions.

Socialization to Art and Science within Remote Indigenous Communities

Nowhere is the alliance of performative, visuospatial, and experiential learning in relation to language socialization more evident than in remote indigenous settings (such as those of Australia and Alaska). Here learning centers on the art and science of heritage and ecological space (Gibson 1979; Ingold 2000). Formal schooling holds little relevance for an economic future in communities where employment opportunities are limited in number and range to government and commerce and often held by outsiders who identify with the national government. Moreover, formal schooling does not define parental interactions and expectations for the young with regard to their aesthetic and practical scientific understanding of the local environment (Watson-Verran and Turnbull 1995). Studies of child and adolescent language socialization in these communities expose the priority of observation and experience over verbal instruction and explanation that holds within literate-oriented families, classrooms, and laboratories.

Acquisition of knowledge of the natural environment by young children

In Australia during the 1970s and 1980s, the Central Desert and Top End of the Northern Territory were primary sites for studies of children's language socialization by linguists and anthropologists. From within one of the most linguistically diverse regions of the world, the Maningrida region in north central Arnhem Land, Hamilton (1981) provides for one group, the Gidjingali, an extensive examination of verbal interaction of adults with children from birth through age nine. Three patterns emerge: (1) young children receive as many gestural messages as they do verbal ones; (2) language support comes through brief comment, warnings, and instructional commands; and (3) open questions occur relatively rarely between adults and children. Information content centers on names of persons and their kinship status. Labels for animate beings, human and nonhuman, matter far more than labels for inanimates. Sharp age-grading and gender segregation are in effect by the time the children reach five years of age. Between the ages of five and nine years, both girls and boys learn to follow adult expectations through observing and following facial expressions and deictic gestures as well as brief verbal commands. In terms of language socialization, the bulk of lexical knowledge young children acquire for plants, animals, insects, and reptiles, as well as land formations, comes through observing the actions of others and through narratives from elders. No decontextualized labels or verbal instruction guide children in their repeated practice of technical skills involved in tracking, spearing fish, catching small animals, and gathering plant materials. Youngsters watch actions, imitate, construct small versions of tools used by their elders, and listen to stories. Children hear recounts of hunting trips, places and land formations, and wet-season practices that go on in informal camp settings. These broad

features of language behavior continue as children learn to categorize flora and fauna as well as movements of the sea and signs of imminent climatic changes.

Resource managers and wildlife rangers working with elders and young people in this region three decades later report similar ways of learning and categorizing local wildlife and ecological conditions (Fordham et al. 2010). Indigenous ecological knowledge sometimes surpasses in complexity and comprehensiveness the taxonomies and understanding of life cycles held by biologists and wildlife resource scientists from universities. Multiple approaches acknowledge the co-dependence of both types of ecological knowledge and value the close observation of indigenous peoples, as well as their long history of cumulative and dynamic information built across generations (Berkes 1999).

Australian linguists have described for many Aboriginal languages the extent to which young children's learning of morphology and lexicon, in particular, are interdependent with their close observation of the natural world. Nouns that refer to animate beings include information not only about sex, but also age and kin relationship. Those that refer to inanimate objects include reference to size, dimension, shape, habitat, and texture. Aboriginal languages are rich in directional and locational terms and make fine distinctions among different types of hitting, cutting, breaking, holding, placing, and carrying (Meggitt 1962; Yallop 1982; Walsh and Yallop 1993).

Changes in socialization patterns

In the 1990s, the national push for assimilation of Aboriginal people into an English-speaking secular, literate, capitalist, and alcohol-tolerant society forcibly disrupted remote communities (Sutton 2009). Linguists and anthropologists turned their attention to documenting how the Australian indigenous viewed the world in the hope of conveying this information to policymakers and educators whose policies were destroying traditional ways of life in remote regions. Recommendations for two-way immersion and bilingual programming resulted (Malcolm, Königsburg, and Collard 2007; Simpson and Wigglesworth 2008; Walsh and Yallop 1993).

These studies also provided substantial subtextual evidence of changing patterns of language socialization, particularly in remote regions (Blake and Dixon 1991; Dixon 1984, 2002). For example, among language groups (such as the Yolngu languages of northeast Arnhem Land) where young children had attended school for at least a decade, adults took up the questioning patterns of school (cf. Simpson and Wigglesworth 2008). They asked questions not to gain information but to elicit from the child information the adults already knew. Rarely did adults address children with open questions ('why,' 'how,' 'when') that required syntactically complex responses. Children, however, addressed such questions to adult visitors to their settlements (Moses and Yallop 2008).

Adaptation of traditional ways of using language by children who attend school appears not only in conversational interactions but also in particular narrative art forms. Skilled narrators, often children, create sand stories in Arandic

areas of Central Australia. Creators draw their stories in cleared areas in the sand and accompany their gestures with speech and gestures that delineate scenes and episodes (Green 2010). In Ernabella in the Central Desert, children, especially girls, imitate and adapt the storytelling and sand-drawing practices of their elders (Eickelkemp 1999). Traditionally focused on ancient history and beliefs, these stories in recent years have been transformed by Ngaanyatjarra girls and others living in the region (speaking Pitjantjatjara or Yankunytjatjara) to relate local events unlikely to be talked about in the village. The word *walka* (Pitjantjatjara usage to mean any meaningful mark) has referred to categories of art-making, such as sketch, print, paint, and draw, as well as markings on animal skins, ceremonial body marking, and the patterns of a bird's feather (Eickelkemp 1999, 2008abc; Myers 2002). These symbolic markings in a past era of tracking, hunting, and gathering, as well as eating bush tucker, conveyed multiple layers of meaning for the verbalized sand stories of children in ways analogous to illustrations in children's literature of the Western world.

The visual arts

Visual arts production by Aboriginal children, going back as far as early missionary schools, aids our understanding of how their art reflects ways of blending image, language, and memories related to scientific and artistic concepts. Records of Aboriginal children's art exist in two forms: narratives and reproductions by early missionaries and ethnographers plus current accounts of locally traditional forms adapted by the young, many of whom now grow up knowing the commercial value that Aboriginal arts can have (Barrett and Croll 1943; Miller 1952; Myers 2002; Thomson 1983; Wallace and Wallace 1968). In the first instance, children's drawings and hand-made toys (in collections such as those of the National Museum of Australia in Canberra and the South Australian Museum in Adelaide) suggest the extent to which children committed to visual memory highly specific features of the natural environment of their remote settlements. In boarding schools and mission schools far away from bush country, indigenous children reflected in their two-dimensional drawings features of ancient wall paintings that can still be found in parts of northern Australia. These drawings invariably portray aspects of the Dreaming, the belief system surrounding the creation of the world, the wandering of ancestral totemic beings to form land and country, and the initiation of cycles of life (Sutton 1988).

Teachers' records from boarding and mission schools report that the children told Dreaming stories in brief form to 'explain' their paintings. English translations of these retellings are filled with inclusive first-person-plural pronouns ('They [the Spirits] gave us hunting things, they gave each clan their land, they gave us our totems, and they gave us our Dreaming' (Aboriginal Arts Board 1977: 11). These children had watched their elders make bark paintings, and, in some cases, sand paintings. Into their drawings, the children brought the same kinds of two-dimensional stylized figures of animals and humans within the landscape that they had seen in art created by adults and heard about in songs and stories.

However, unlike most well-known art works (including paintings on canvas) by adult Aboriginals, the earliest paintings of Aboriginal children tend to fill the entire space on their paper and represent the sky, sea, and landscape, with animals and humans placed on top of these backdrops (Wallace and Wallace 1968). In their paintings, Central Desert children reflect with precision the range of shadings of ochre in their desert landscape. Their painted renderings of 'real' historical incidents generally portray highly stylized human figures without attention to musculature, facial features, or precise skin coloring.[1]

Museum collections of toys of indigenous Australian children reflect their keen visual memory and adeptness in adapting found objects (e.g. animal knucklebones used as stones and tin cans for kick-the-tin games; Kartinyeri 2003). Materials at hand, discarded, discovered, reshaped, and integrated, have traditionally found their way into children's play and toy-making. Aboriginal toys and games documented through artifacts and ethnographic information reflect a preponderance of games requiring visual precision and physical dexterity (Haagen 1994).

Adolescent Language

The few sources reporting language use by indigenous adolescents living in remote regions of Australia and Alaska center on patterns of adaptation and incorporation of internet technologies into daily existence. Three studies illustrate ways in which adolescents living with one foot in traditional life and the other in the world of entertainment via the internet and television use language in their learning of art and science. These teens take part intermittently in formal education, but persistently move toward a syncretism of old and new in habits, skills, values, and self-identity in the bulk of their time into their late twenties. Many view themselves in an orbit between remote settlement and urban centers through which they will move back and forth in their adult lives (Sutton 2009).

The first of the studies of adolescent language was carried out among Areyonga teenage Pitjantjatjara speakers in the Central Australian Desert (Langlois 2004). Teenagers appear to be replacing kin terms in local languages with lexical items from English. However, contrary to general expectations in language shift, these loans allow the teenagers to add distinctions and to express new concepts pertaining to relationships (e.g. terms that distinguish younger male sibling from older male sibling). Thus, teenage speakers of Pitjantjatjara borrow to fill lexical gaps for these traditional relations as well as for the latest technologies that come into their community. Among Areyonga teenage Pitjantjatjara speakers, stories tend to show continuity of actions, one after the other, past action followed by yet another, rather than embedding of actions within an act and consequence chain. A chaining linearity appears to dominate in their narratives; in other words, a priority in time need not be morphologically marked as either temporal or causal. These changes within indigenous language accounts of science and art parallel the focus in school recitation on given-state and in-the-moment descriptions, but depart from proc-

esses of both arts production the young have witnessed and natural life cycles recounted in traditional narratives.

A second account from Aboriginal adolescents in the Central Desert and Northern Australia relays the adaptive learning skills of artists in social enterprise, dance, and music (Kral 2007, 2008). In Beswick or Wugularr in the Northern Territory, a community of some 450 people who retain Roper River Kriol as their usual language, young people have created a community art project, Djilpin Arts. The young manage the enterprise as a culture center and, in doing so, they set out to learn from their elders traditional means of collecting natural bush medicines and plants. Intergenerational links are forged in the collection of sugar bag honey, experimentation with soap production, and design of packaging. Joint socialization toward economic ends motivates old and young to combine their areas of specialization, open channels of talk, and bring graphic design together with text production. The young and their elders work together to make soap, lip balm, and candles to sell during festivals at the culture center. The group employs local young men to film the arts and cultural activities of the community. Here science and art merge. The young people use Kriol for their own group interactions when editing one another's work, for example, but they speak English when they engage with visitors during festival times and in their musical performances.

In the Western Desert, young people who work in a community center established in Wingellina in 1992 produce CDs and regularly post performances to YouTube. Older youths teach younger peers, introducing them to a wide array of skills for searching internet sites. Without verbal directives or specific instructions, young people lay down tracks sequentially and create CDs that they rework repeatedly in subsequent sessions. As festival time approaches, they finalize their CDs, develop a sleeve with their artwork, and provide bilingual lyrics of their songs (Kral 2008; for a comparative analysis with urban Aboriginals in Western Australia, see Malcolm, Königsberg, and Collard 2002).

Margaret Mead's (1970) prefigurative, postfigurative, and co-figurative socialization all come together in these indigenous communities. Mead defined 'postfigurative' socialization as that in which elders teach the young, 'cofigurative' socialization as that in which children and adults learn from their peers, and 'prefigurative' socialization as that in which the young instruct their elders. Peers demonstrate and, when asked, explain to one another technical strategies, and the young are available to demonstrate and narrate processes with their elders. In the studios of community arts centers of remote communities, Aboriginal youths and their elders (generally males only) share the recording space and equipment. Female elders travel into the bush with the young to collect plants and herbs and retell narratives from their childhood; male elders advise the young on traditional dance and song and sometimes take part in production of the CDs. The young work with their peers and also with elders as festival times approach. Among adolescents, co-figurative peer-to-peer socialization takes place around effective use of software, writing of songs, production of text for CD covers, and creation of instructive CDs on how to use specific software programs. New genres, necessary to bringing their local product in line with the style of commercially available

products, come into use. Ingredient lists for beauty products made of local herbs and plants motivate elders not only to tell stories of the past but to relate descriptions of appropriate stages of plant development for harvesting in order to ensure the best-quality product. Market requirements for quality and presentation press young and old to plan carefully their combinations of graphic design, printed instructions, ingredient lists, and brief traditional histories of these ingredients. These initiatives begin to address the void of decades in which no local economic opportunities or educational motivation existed in remote indigenous locations. Community centers, festivals, and sale of products and services through the internet bring young and old together in meaningful work that draws on traditional art and science and links to relevant development of literacy, management, and mathematical skills (Kral 2008).

A third study of adolescent indigenous language speakers comes from Yupik speakers in remote Alaskan villages. Wyman (2004), studying these speakers from middle childhood into young adulthood, shows how descriptions of sequenced actions, such as a seal hunt, find their way into narratives told primarily within specific times and places. Young people among the Yupik tell one another stories about their individual and shared experiences with subsistence, redistributing and underscoring information they gain about the environment along with their own perspectives on undertaking adult roles, relationships, and risks over time (L. Wyman, personal communication). Stories told among young people making exploratory excursions at the margins of approaching hunting or fishing seasons appear to allow the young to test theories for and about themselves and their standing as future subsistence participants and adult members of their society. The frequency and content of these stories vary by gender and also by stage of season, as well as in relation to a sense of endangerment about the future of the society. Contrary to the many oversimplifications of how indigenous learners living in remote regions learn ecological knowledge, initiates undertake multiple means of taking in information on a vast array of highly technical subjects and skills (Lomawaima and McCarty 2006).

Planned Learning Environments and the Separation of Art and Science

Social scientists of several disciplines have described both formal and informal learning environments that advance knowledge about and applications of skills in science and art. These range from literate-oriented families to classrooms, museums, marine life centers, laboratories, studios, and rehearsal spaces.

The language of learning science and art in school-oriented families

As a result of their focus on preparing their children for academic success, upper- and middle-income families direct their children from infancy forward to name,

describe, sequence, and compare objects. Multiclausal sentences, past and future tense usage, and questions characterize parental talk to children (Hart and Risley 1995, 1999; Lareau 2003; Vernon-Feagans 1996). During visits to museums, exhibitions, and parks, along with participation in sports and hobbies, parents link current experiences to school topics (Bell, Zimmerman, and Reeve 2008; National Research Council 2009).

In these families, picture books and early story books include fictional and nonfictional topics related to science and art. Bedtime stories ensure attention to illustrative representations of animals, seasonal change, and famous painters and their subjects. Museums sponsor scores of children's books that link science and art and their common processes. During middle childhood, families watch television programs and visit museums and parks that address current topics in scientific exploration and discovery. Parents talk with their children about practices and technologies that make predictions and advances in science possible. This 'concerted cultivation' of children looks ahead to formal education, while free play and family projects inspired by curiosity and implemented without commercial products fall out of favor in comparison with learning opportunities that help the young to envision themselves studying science or seeking employment in science-related fields (Chabon 2009; Heath 2006, 2008; Louv 2006; National Research Council 2009; Tai et al. 2006).

Formal study of science and art

Studies of art and science classrooms reveal the importance of learning labels and taxonomies and of handling instruments and technologies. Complementing oral and written language instruction, especially of primary students, are dramatic role-play, visuospatial activities, and spectator events (e.g. videos) (e.g. Fleer 2009). For adolescents, instructors have found highly effective increased use of gesture to demonstrate concepts or to focus on metacognitive processes or mnemonic strategies (Roth 2000).

The younger the learner, the more likely there are to be opportunities for 'taking part' in discovery, creation, and experimentation in both art and science classes. Young learners are also more likely than their older peers to hear narratives about art and science and to be asked to create their own stories about their work (Heath and Wolf 2004). Both art and science presuppose a theory of mind that grasps the intentions and ways of knowing of others distant from the current scene, a realization that primary teachers take into account when they devise means for children to embody roles in which they can 'be' scientists and artists' (Heath and Wolf 2005). Sociodramatic play and narrative development help young learners to bridge from colloquial, narrative, and informal language to the formal language demands of science (Lemke 1990).

As levels of study advance through formal education, the language socialization that instructors undertake increasingly emphasizes defining, identifying, explaining, hypothesizing, and critically reviewing. In both science and art, visual representations in a wide variety of forms (e.g. videos, photographs, diagrams,

graphs, charts, timelines, paintings, and demonstrations) figure centrally in textbooks and assessments. Accurate interpretation of these materials with their verbal supports (oral and written) determines competency. Often students must demonstrate specific levels of linguistic competency before they may take part in scientific or artistic activities in clubs, after-school programs, and high-level classes.[2]

With advancement in formal education, learners must also master specific processes of investigation, verification, invention, critique, and discovery (Bowker and Star 1999; Soep 2006). In art, they have to learn processes and techniques as well as historical and aesthetic dimensions of various forms, artists, and schools. In science, they must know and practice a readily recognized form of scientific objectivity and be able to offer theories as rationales for the universality of science (Star and Griesemer 1989). Artists and scientists alike constantly engage with the hypothetical. Laboratories, studios, and rehearsal spaces reflect similar frequencies in their use of technical lexicon, modal verbs, questions related to process, and hypothetical propositions (Heath, Paul-Boehncke, and Wolf 2007).

Language in workplaces

The interdependence of gesture, oral language, and forms of representation (e.g. diagrams, photographs, models) is ubiquitous in workplaces of scientists. In the laboratory, physicists set up visual domains through combinations of gesture, talk, sketches, and diagrams in their attempts to achieve mutual understanding and a working consensus around experimental findings (Ochs, Gonzales, and Jacoby 1996). Gestural moves reinforce verbal deictics (e.g. 'here,' 'there') and create narrative and envisoned worlds of work being represented – whether from past experiments or toward performances projected (see Heath (forthcoming) on the three major functions of discourse 'chunks' in collaborative production and rehearsal of scientific work). Speakers blend the identity of scientist and the arena of inquiry or joint planning and thus capture 'the animate physicist and the inanimate physical entity undergoing some change of state' (Ochs, Gonzales, and Jacoby 1996: 348).

Sociologically oriented studies of science laboratories have shown the ideological and verbal character of participants' collaborative work (Latour 1986, 1987, 1988; Latour and Woolgar 1986). Talk surrounds and often depends on 'artifact' either currently present or referenced from past experiments (Lynch 1985). Visuospatial resources – graphs, charts, models – have to be read in detail by all. Gestures and deictic references attune visual focus to props and support and extend verbal work. Laboratories operate as 'think collectives' in which participants have 'ideovisions' (stylized ideograms) as well as unique uses of language (Fleck 1979 [1935]). French sociologist Bruno Latour underscores self-reports of scientists and artists who point to the expectation that initiates learn to read interactions, numerous symbol systems, and signals for conformity to the ethic of individual responsibility in the life of the laboratory (Latour 1988; Latour and Woolgar 1986). The lives of those working in art studios are similarly 'joined,' and

creative collaborators depend on common definitions of problems, deliberative approaches to solutions, and willingness to present evidence in a host of ways to support deliberation and even argument in the midst of action (John-Steiner 2000; Tharp 2003).

The interdependence of spatial alignment, gesture, and verbal interaction in the work of science comes not only from laboratory studies but also from analyses of how indigenous and Western-trained scientists, such as pilots and air traffic controllers, navigate their everyday worlds of work (Gladwin 1970). Much of the 'expertise' on which navigators now depend comes from inanimate objects (robots, computer transmissions, etc.) that communicate to human interpreters, whose visual observations translate into collaborative action to steer a ship into harbor or manage take-off and landing of a plane or space capsule on earth, in space, or on the moon or Mars (Goodwin 1994, 1995; Hutchins 1995; Hutchins and Klausen 1995). These and other studies of discourse in workplaces devoted to uses of science and technology stress the need for initiates to become fluent users of particular grammatical forms, agreed-upon 'unique' naming practices, and group-specific ways to defuse potential interactional difficulties (e.g. Drew and Heritage 1992).

Conclusions

As advanced nations move their economic base from manufacturing to finance, electronic technologies, and service industries, formal education – especially higher-education institutions – will be the most visible environment to support invention, discovery, and exploration in both science and the arts. However, informal modes of socialization into art and science will also grow rapidly as schools urge museums, botanical parks, and zoos to complement the curricular work of formal education (National Research Council 2009). The push around the world for environmental conservation and sustainability, healthy living, and indigenous resource management will ensure that 'researchers beyond the university walls' sharpen the vision and resolve of individuals and groups for science and art (Finnegan 2005). This promotion is likely to draw increasing attention to the dominant role of long-standing fundamentals in the learning of art and science – looking, tracing, re-enacting, and playing, which are essential supports for language socialization.

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NOTES

1 I am indebted to Nancy Michaelis, formerly within the curatorial department of the National Museum of Australia, for access in 2008 to the museum's collection of children's drawings and paintings. I also remember with appreciation the access that Peter Sutton, curator with the South Australian Museum, gave me at several points during the 1980s to that museum's collections of children's art work.

2 These generalizations are derived from review of state standards in the United States for science and art between 2000 and 2005 and from introductory descriptions of science teaching in nations included in the PISA international comparisons of subject-matter achievement levels.

REFERENCES

Aboriginal Arts Board. (1977) *The Aboriginal Children's History of Australia*. Adelaide, Australia: Rigby Publishers.

Barrett, C. and Croll, R. (1943) *Art of the Australian Aboriginal*. Melbourne, Australia: The Bread and Cheese Club.

Barsalou, L. W. (2008) Grounded cognition. *Annual Review of Psychology* 59: 617–45.

Bell, P., Zimmerman, H., and Reeve, S. (2008) Distributed expertise in a science center: Social and intellectual role-taking by families. *Journal of Museum Education* 33(2): 143–52.

Bender, J. and Marrinan, M. (2010) *The Culture of Diagram*. Stanford, CA: Stanford University Press.

Berger, C., Roloff, M., and Roskos-Ewoldsen, D. (eds.) (2009) *The Handbook of Communication Science*. 2nd ed. Thousand Oaks, CA: Sage.

Berkes, F. (1999) *Sacred Ecology: Traditional Ecological Knowledge and Resource Management*. Philadelphia, PA: Taylor and Francis.

Blake, B. and Dixon, R. (eds.) (1991) *Handbook of Australian Languages*. Oxford: Oxford University Press.

Bowker, G. and Star, S. (1999) *Sorting Things Out: Classification and Its Consequences*. Cambridge, MA: MIT Press.

Bruner, J. (1983) *Child's Talk: Learning to Use Language*. New York: W. W. Norton.

Chabon, M. (2009) *Manhood for Amateurs*. New York: Harper Collins.

Deacon, T. (1997) *The Symbolic Species: The Co-Evolution of Language and the Brain*. New York: Norton.

Deacon, T. (2006) The aesthetic faculty. In M. Turner (ed.), *The Artful Mind: Cognitive Science and the Riddle of Human Creativity*. 21–57. New York: Oxford.

Dixon, R. (1984) *Searching for Aboriginal Languages: Memoirs of a Field Worker*. St. Lucia, Australia: University of Queensland Press.

Dixon, R. (2002) *Australian Languages: Their Nature and Development*. Cambridge: Cambridge University Press.

Donald, M. (1991) *Origins of the Modern Mind: Three Stages in the Evolution of Culture and Cognition*. Cambridge, MA: Harvard University Press.

Donald, M. (2001) *A Mind So Rare: The Evolution of Human Consciousness*. New York: Norton.

Donald, M. (2006) Art and cognitive evolution. In M. Turner (ed.), *The Artful*

Mind: Cognitive Science and the Riddle of Human Creativity. 3–20. New York: Oxford University Press.

Drew, P. and Heritage, J. (eds.) (1992) *Talk at Work: Interaction in Institutional Settings*. New York: Cambridge University Press.

Eickelkamp, U. (1999) *'Don't Ask for Stories…' the Women from Ernabella and Their Art*. Canberra, Australia: Aboriginal Studies Press.

Eickelkamp, U. (2008a) 'I don't talk story like that': On the social meaning of children's sand stories at Ernabella. In J. Simpson and G. Wigglesworth (eds.), *Children's Language and Multilingualism: Indigenous Language Use at Home and School*. 79–102. London: Continuum Press.

Eickelkamp, U. (2008b) Play, imagination, and early experience: Sand storytelling and continuity of being among Anangu Pitjantjatjara girls. In G. Robinson, U. Eickelkamp, J. Goodnow, and I. Katz (eds.), *Contexts of Child Development: Culture, Policy and Intervention*. 138–52. Darwin, Australia: Charles Darwin University.

Eickelkamp, U. (2008c) (Re)presenting experience: A comparison of Australian Aboriginal children's sand play in two settings. *International Journal of Applied Psychoanalytic Studies* 5: 12–50.

Finnegan, R. (2002) *Communicating: The Multiple Modes of Human Interconnection*. London: Routledge.

Finnegan, R. (ed.) (2005) *Participating in the Knowledge Society: Researchers Beyond the University Walls*. New York: Palgrave Macmillan.

Fleck, L. (1979 [1935]) *Genesis and Development of a Scientific Fact*. Chicago, IL: University of Chicago Press.

Fleer, M. (2009) Supporting scientific conceptual consciousness or learning in 'a roundabout way' in play-based contexts. *International Journal of Science Education* 31(8): 1069–89.

Fordham, A., Fogarty, W., Corey, B., and Fordham, D. (2010) *Knowledge Foundations for the Development of Sustainable Wildlife Enterprises in Remote Indigenous Communities of Australia*. Canberra, Australia: ANU Centre for Aboriginal Economic Policy Research Working Paper No. 62.

Gibson, J. (1979) *The Ecological Approach to Visual Perception*. Boston, MA: Houghton Mifflin.

Gladwin, T. (1970) *East Is a Big Bird: Navigation and Logic on Puluwat Atoll*. Cambridge, MA: Harvard University Press.

Goodwin, C. (1994) Professional vision. *American Anthropologist* 96: 606–33.

Goodwin, C. (1995) Seeing in depth. *Social Studies of Science* 25: 237–74.

Green, J. A. (2010) *Between the Earth and the Air: Multimodality in Arandic Sand Stories*. Dissertation. Melbourne, Australia: Melbourne University.

Haagen, C. (1994) *Bush Toys: Aboriginal Children at Play*. Canberra, Australia: Aboriginal Studies Press.

Hamilton, A. (1981) *Nature and Nurture: Aboriginal Child-Rearing in North-Central Arnhem Land*. Canberra, Australia: Australian Institute of Aboriginal Studies.

Hari, R. and Kujala, M. (2009) Brain basis of human social interaction: From concepts to brain imaging. *Physiological Review*. 89(2): 453–79.

Hart, B. and Risley, T. R. (1995) *Meaningful Differences in the Everyday Experience of Young American Children*. Baltimore, MD: Brookes.

Hart, B. and Risley, T. R. (1999) *The Social World of Children Learning to Talk*. Baltimore, MD: Brookes.

Heath, S. B. (2000) Seeing our way into learning. *Cambridge Journal of Education* 30(1): 121–32.

Heath, S. B. (2006) Commentary 2. Building the micros toward seeing the macro. *Text: Special Issue: Family Discourse, Framing Family* 26(4/5): 627–34.

Heath, S. B. (2008) Foreword. In J. Simpson and G. Wigglesworth (eds.), *Children and*

Multilingualism: Indigenous Language Use at Home and School. ix–xiii. London: Continuum International.
Heath, S. B. (forthcoming) Seeing our way into learning science in informal environments. In W. Tate and C. Yeakey (eds.), *Research on Schools, Neighborhoods and Communities: Toward Civic Responsibility*. Washington, DC: AERA.
Heath, S. B., Paul-Boehncke, E., and Wolf, S. (2007) *Made for Each Other: Creative Sciences and Arts in the Secondary School*. London: Creative Partnerships.
Heath, S. B. and Wolf, S. (2004) *Visual Learning in the Community School*. London: Creative Partnerships.
Heath, S. B. and Wolf, S. (2005) *Dramatic Learning in the Primary School*. London: Creative Partnerships.
Hutchins, E. (1995) *Cognition in the Wild*. Cambridge, MA: MIT Press.
Hutchins, E. and Klausen, T. (1995) Distributed cognition in an airline cockpit. In Y. Engestrom and D. Middleton (eds.), *Cognition and Communication at Work*. 15–34. Cambridge, U.K.: Cambridge University Press.
Ingold, T. (2000) *The Perception of the Environment: Essays on Livelihood, Dwelling, and Skill*. New York: Routledge.
John-Steiner, V. (2000) *Creative Collaboration*. New York: Oxford University Press.
Kartinyeri, D. (2003) *Bush Games and Knucklebones*. Broome, WA: Magabala Books.
Kemp, M. (1990) *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat*. New Haven, C. N.: Yale University Press.
Kosslyn, S. M., Ganis, G., and Thompson, W. L. (2006) Neural foundation of imagery. *Nature Reviews Neuroscience* 2: 635–42.
Kral, I. (2007) *Writing Word – Right Way! Literacy and Social Practice in the Ngaanyatjarra World*. Dissertation. Canberra, Australia: Australian National University.
Kral, I. (2008) Youth, learning and enterprise in remote Aboriginal Australian communities. Unpublished paper. Canberra, Australia: Australian National University.
Kuhl, P. K. (2007) Is speech learning 'gated' by the social brain? *Developmental Science* 10(1): 110–20.
Kulick, D. (1992) *Language Shift and Cultural Reproduction: Socialization, Self, and Syncretism in a Papua New Guinean Village*. New York: Cambridge University Press.
Langlois, A. (2004) *Alive and Kicking: Areyonga Teenage Pitjantjatjara. Pacific Linguistics 561*. Canberra, Australia: ANU Research School of Pacific and Asian Studies.
Latour, B. (1986) Visualization and cognition: Thinking with eyes and hands. *Knowledge and Society* 6: 1–40.
Latour, B. (1987) *Science in Action*. Cambridge, MA: Harvard University Press.
Latour, B. (1988) *Science in Action: How to Follow Scientists and Engineers through Society*. Cambridge, MA: Harvard University Press.
Latour, B. and Woolgar, S. (1986) *Laboratory Life: The Construction of Scientific Facts*. Beverly Hills, CA: Sage.
Lareau, A. (2003) *Unequal Childhoods: Class, Race and Family Life*. Berkeley, CA: University of California Press.
Lemke, J. (1990) *Talking Science: Language, Learning, and Values*. Norwood, NJ: Ablex.
Lomawaima, T. and McCarty, T. (2006) *To Remain an Indian: Lessons in Democracy from a Century of Native American Education*. New York: Teachers College Press.
Louv, R. (2006) *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder*. Chapel Hill, NC: Algonquin Books.

Lynch, M. (1985) *Art and Artifact in Laboratory Science*. Boston, MA: Routledge and Kegan Paul.

Malcolm, I. G., Königsberg, P., and Collard, G. (2002) *Umob Deadly: Recognized and Unrecognized Literacy Skills of Aboriginal Youth*. Mount Lawley, WA: Centre for Applied Language and Literacy Research, Edith Cowan University.

Mead, M. (1970) *Culture and Commitment: A Study of the Generation Gap*. London: The Bodley Head Ltd.

Meggitt, M. J. (1962) *Desert People: A Study of the Walbiri Aborigines of Central Australia*. London: Angus and Robertson.

Meltzoff, A. (2005) Imitation and other minds: The 'like me' hypothesis. In S. Hurley and N. Chater (eds.), *Perspectives on Imitation: From Neuroscience to Social Science, vol. 2*. 55–77. Cambridge, MA: MIT Press.

Meltzoff, A., Kuhl, P. K., Movellan, J., and Sejnowski, T. J. (2009) Foundations for a new science of learning. *Science* 325: 284–8.

Meltzoff, A. and Prinz, W. (eds.) (2002) *The Imitative Mind: Development, Evolution and Brain Bases*. Cambridge: Cambridge University Press.

Miller, M. D. (1952) *Child Artists of the Australian Bush*. London: G. G. Harrap.

Moses, K. and Yallop, C. (2008) Questions about questions. In J. Simpson and G. Wigglesworth (eds.), *Children's Language and Multilingualism: Indigenous Language Use at Home and School*. 30–56. London: Continuum Press.

Myers, F. R. (2002) *Painting Culture: The Making of an Aboriginal High Art*. Durham, NC: Duke University Press.

National Research Council of the National Academies (2009) *Learning Science in Informal Environments: People, Places and Pursuits*. Washington, DC: The National Academies Press.

Ochs, E., Gonzales, P., and Jacoby, S. (1996) 'When I come down I'm in the domain state': Grammar and graphic representation in the interpretive activity of physicists. In E. Ochs, E. Schegloff, and S. Thompson (eds.), *Interaction and Grammar*. 328–69. Cambridge: Cambridge University Press.

Pfeifer, R. and Bongard, J. C. (2006) *How the Body Shapes the Way We Think: A New View of Intelligence*. Cambridge, MA: MIT Press.

Ramadas, J. (2009) Visual and spatial modes in science learning. *International Journal of Science Education* 31(3): 301–18.

Rizzolatti, G. and Craighero, L. (2004) The mirror-neuron system. *Annual Review of Neuroscience* 27: 169–92.

Rogoff, B. (2003) *The Cultural Nature of Human Development*. New York: Oxford University Press.

Roth, W.-M. (2000) From gesture to scientific language. *Journal of Pragmatics* 32: 1683–714.

Schieffelin, B. B. (1990) *The Give and Take of Everyday Life: Language Socialization of Kaluli Children*. Cambridge: Cambridge University Press.

Schnotz, W. (2002) Towards an integrated view of learning from text and visual displays. *Educational Psychology Review* 14(1): 101–19.

Simpson, J. and Wigglesworth, G. (2008) *Children's Language and Multilingualism: Indigenous Language Use at Home and School*. London: Continuum.

Soep, E. (2006) Critique: Assessment and the production of learning. *Teachers College Record* 108(4): 748–77.

Speer, N. K., Reynolds, J., R. Swallow, K. M., and Zacks, J. M. (2009) Reading stories activates neural representations of visual and motor experiences. *Psychological Science* 20(8): 989–99.

Stafford, B. (1994) *Artful Science: Enlightenment Entertainment and the Eclipse of Visual Education*. Cambridge, MA: MIT Press.

Stafford, B. (2007) *Echo Objects: The Cognitive Work of Images*. Chicago, IL: University of Chicago Press.

Star, S. L. and Griesemer, J. (1989) Institutional ecology, translations, and

boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology. *Social Studies of Science* 19: 387–420.
Sutton, P. (2009) *The Politics of Suffering*. Melbourne, Australia: Melbourne University Press.
Sutton, P. (ed.) (1988) *Dreamings: The Art of Aboriginal Australia*. New York: The Asia Society Galleries.
Suwa, M. and Tversky, B. (1997) What architects and students perceive in their sketches: A protocol analysis. *Design Studies* 18: 385–403.
Tai, R. H., Liu, C., Maltese, A., and Fan, X. (2006) Planning early for careers in science. *Science* 312: 1143–4.
Tharp, T. (2003) *The Creative Habit: Learn It and Use It for Life*. New York: Simon and Schuster.
Thomson, D. (1983) *Children of the Wilderness*. South Yarra, Australia: Curry O'Neil Ross.
Uttal, D. and O'Doherty, K. (2008) Comprehending and learning form 'visualization': A developmental perspective. In J. K. Gilbert, M. Reiner, and M. Nakhleh (eds.), *Visualization: Theory and Practice in Science Education*. 53–72. New York: Springer.
Vernon-Feagans, L. (1996) *Children's Talk in Communities and Classrooms*. Cambridge, MA: Blackwell.
Wallace, P. and Wallace, N. (1968) *Children of the Desert*. Melbourne, Australia: Thomas Nelson.
Walsh, M. and Yallop, C. (1993) *Language and Culture in Aboriginal Australia*. Canberra, Australia: Australian Studies Press.
Watson-Verran, H. and Turnbull, D. (1995) Science and other indigenous knowledge systems. In S. Jasanoff, G. E. Markle, J. C. Petersen, and T. Pinch (ed.), *Handbook of Science and Technology Studies*. Rev. ed. 115–39. Thousand Oaks, CA: Sage.
Wolf, B. J. (2001) *Vermeer and the Invention of Seeing*. Chicago, IL: University of Chicago Press.
Wyman, L. (2004) Language shift, youth culture and ideology: A Yup'ik example. Dissertation. Stanford, CA: Stanford University.
Yallop, C. (1982) *Australian Aboriginal Languages*. London: Andre Deutsch.