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Implementing and Sustaining Science Curriculum Reform: A Study of Leadership Practices Among Teachers Within a High School Science Department

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Abstract: This study presents a description and analysis of a ninth-grade integrated science curriculum developed and implemented by teachers within a high school science department and subsequently sustained for over 25 years. The Integrated Science Program (ISP) at Lakeside Southwest High School depicted here offers a unique example of longitudinal science education reform. In this study, we examined ISP as an artifact of teacher leadership. Findings affirmed the importance of shared philosophical purpose among teachers, attention to public perceptions, staff stability, the distribution of responsibilities, and instructional coherence. This study also demonstrated how curricular reforms might change over time in response to contextual pressures as was the case with the equity challenges faced by the current teachers of ISP. © 2009 Wiley Periodicals, Inc. J Res Sci Teach 46: 813–835, 2009

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Despite attempted reforms in science education over the past two decades, practices running counter to those recommended in recent science standards documents and various national curricula (e.g., Ministry of Education, 1993; National Research Council, 1996; Qualifications and Curriculum Authority, 2001) have been remarkably resistant toward efforts to change them (Anderson, 2007; Davis, 1997). Science education literature is full of examples of innovative curricular designs, often funded by short-term grants, giving little indication of how, or even if, these programs are sustained over long periods of time. Further, there is a dearth of research on how schools that have successfully implemented reforms consistent with science standards have adjusted to contextual pressures arising over time.

In this study, we address this gap in the literature by depicting the implementation and subsequent development of a ninth-grade integrated science course that has been offered for over two decades in a public high school in the United States. The Integrated Science Program (ISP) at Lakeside Southwest High School (Southwest)[1] offers a unique example of curricular innovation that enjoys broad community and school district personnel support and has continued to develop over time to respond to changing educational climates and student demographics. Further, it appears to offer a powerful counterargument to the popular notion that teacher autonomy is curtailed when individual teachers share a common curriculum.

Our purpose is not to make claims about ‘‘best practices’’ in the teaching of science, nor to make claims about the success of this program. Rather, the premise of our study is that understanding leadership practices at the school and department levels is an important, necessary, and often neglected aspect of curricular reform efforts. Therefore, the leadership practices described in the present study refer to those *among* the teachers themselves and not necessarily those of the district or school administrators, despite the importance of such support.

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We offer here an intrinsic case study (Stake, 2005) of sustained, reform-based, curricular reform at a ninth-grade level with the intention of illuminating some of these practices. To describe the program without reference to the way the local context influenced the framing and solution of particular problems regarding the design and implementation of the curriculum would overlook important insights about how science reforms are enacted in schools. Therefore, in this study, we seek to examine ISP at Southwest as an artifact of leadership and attempt to uncover the practical wisdom the designers and implementers embedded in this program. Following this analysis, we compare this practical wisdom with some of the dilemmas commonly encountered in departmental level science reform and offer some implications for such reforms and further research based on our findings.

A Brief Description of ISP

ISP is an introductory science course taken by most, but not all, of the ninth-grade students at Southwest High School. Each of the six veteran teachers is assigned three sections of the course and share a common curriculum. Currently, the curriculum consists of ten units from various science disciplines (see Table 1) examined through the course's unifying focus on the first law of thermodynamics, more commonly known as the law of conservation of energy. The course emphasizes science processes, the unity of science, the nature of science, science skills, and the development of reasoning so ISP can serve as a foundational experience for any of the other 20 science courses offered at Southwest. No textbook is used, and the teachers have developed all laboratory activities, handouts, and readings selections.

ISP is a course that was designed to help students develop the necessary skills for scientific inquiry. In science education, the term ''inquiry'' is often given multiple meanings by science teachers and others within science education reform efforts (Crawford, 2007; Lawson, 2005; Windschitl, 2004). Windschitl's (2003)

Table 1
Units in the ISP curriculum

ISP unit	Topics covered
Unit one	Measurement
	Graphing
	Density
Unit two	Conduction
	Convection
	Radiation
	Conservation law
Unit three	Phase change
	Specific heat
	Global winds
Unit four	Seasons
	Climate
	Greenhouse effect
Unit five	Chemical reactions
	Balancing equations
Unit six	Photosynthesis
	Respiration
	Ecology
Unit seven	Human power
	Inclined planes
	Levers
Unit eight	Resistance
	Cost of electricity
	Production of light
Unit nine	Earthquakes
	Plate tectonics
Unit ten	Radioactive decay
	Fission
	Lives of stars (or other teacher selected topics)

definition of *structured* inquiry, ‘‘in which the teacher presents a question for which the students do not know the answer, and students are given a procedure to follow in order to complete the inquiry,’’ (p. 114) generally seems applicable to the activities in ISP. However, this is not necessarily to say students are engaging in ‘‘cookbook’’ types of activities to confirm scientific knowledge. The focus of these activities is to provide students with an evidentiary basis for the expression of the first law of thermodynamics across a variety of scientific fields. This sort of approach can be related to Rudolph’s (2005) description of certain types of inquiry that ‘‘provide opportunities for students to grapple with questions shaped by disciplinary frameworks’’ (p. 805).

A sample of such an ISP activity, called ‘‘Conduction and the Conservation Law,’’ is shown in Appendix A. Salient features of this sample and other ISP activities include a focus on data gathering, laboratory skills, guided reasoning based upon evidence, and assessing and addressing student conceptions that may conflict with desired scientific understandings. It is also relevant to the year-long theme of examining the evidence for the law of conservation of energy—a feature found in all of the ISP activities.

Theoretical Framework

Halverson (2004) uses Aristotle’s description of *phronesis*, or practical wisdom, to describe the means by which educational researchers can access the knowledge skilled educational leaders use in making decisions that might otherwise remain hidden. By examining an *artifact*, something that by definition is a product of phronesis, the history of how the artifact came to be and what problems it was designed to solve can be seen. It is important to clearly state that the artifact under consideration in this study is ISP itself, because it was developed as a tool to address a number of specific concerns within the Science Department at Southwest as will be described below.

Halverson (2004) describes the importance of understanding artifacts as tools and products, noting, ‘‘School leaders work with abstract artifacts such as programs, policies, and procedures the way painters work with brushes, canvasses, and palettes . . . Artifacts are the tools leaders use to establish structures for shaping social interactions, work practices, and learning in schools,’’ (p. 100).

In this study, we use Halverson’s guidelines for the production of phronetic narratives to describe the practical wisdom reflected in ISP’s design and modification over the past 20 years. Features of this approach include examining how the goals, resources, and strategies employed by the designers of ISP affected how problems were set and then solved. In our analysis, we look specifically at the affordances of the artifact—what ISP enabled the designers to do—as well as the constraints faced in the design and modification phases. We also examine the ‘‘lessons learned’’ from ISP as a designed artifact.

Methodology

The idea for investigating the history of ISP originated when Larkin began working with student teachers as a university supervisor at Southwest High School in 2005. Over the course of his supervisory work, he became familiar with ISP and developed a professional relationship with a number of teachers in the Science Department. As a former high school science teacher, he recognized both the uniqueness of the program and its longevity as attributes meriting further study.

One overarching methodological commitment to our work in this study was to focus our efforts on what was good and worthy, rather than on what might be wrong. Lawrence-Lightfoot (1983) has written about the tradition in social science regarding ‘‘the uncovering of malignancies and the search for their cures’’ (p. 10). We sought to avoid such an outcome. This does not imply that we chose to ignore problems, but rather we began the research from a position of respect for teacher knowledge and empathy for their struggle to forge a good science experience for ninth graders.

This research was conducted primarily by interviews during the spring of 2006, each one lasting between 40 and 80 minutes. The first interview was conducted with the department chair, Gary Parsons, during the school day over his preparation and lunch periods. The second was conducted over two consecutive preparation periods with four of the ISP teachers. During this interview, a number of other science teachers overheard and joined the conversation for brief periods of time as they passed through the room while the researchers quickly retrieved more consent forms so their contributions could be included. A third interview

Table 2
Demographic information for participants

Teacher	Years of experience (as of 2006)	Total years teaching ISP	Other courses taught	Current ISP responsibilities
Les Lombardi	20	3	Biology	Retired
Alan Crane	24	24	Astronomy	Revision of tests
Gary Parsons	23	23	Aerospace, Biology, Chemistry	Administrative
Brent Stetson	18	18	Astronomy	Website, lab materials
Cora Jackson	10	10	Biology	Revision of handouts, making copies
Nick O'Malley	9	9	Anatomy and Physiology	Revision of tests, handouts
Carolyn Kaiser	12	12	AP biology, Anatomy & Physiology	Administrative

was conducted with the remaining ISP teacher after the end of the school day in his classroom. At the time of the interviews, each of the six teachers had between 8 and 25 years experience teaching ISP at Southwest High School and all were identified racially as white. A summary of relevant participant demographic information is shown in Table 2.

All three of this study's authors participated in conducting these interviews from the protocols (adapted from Halverson, personal communication, 3/7/06) as shown in Appendix B. The final interview was conducted off-site with the retired department chair, Les Lombardi, who was one the original designers of the ISP curriculum. The first author conducted this interview. All interviews were recorded and transcribed. Each author reviewed the data individually and hand coded for the phronetic narrative themes described above. The authors then formed a consensus regarding their individual analyses.

Additionally, we examined a large volume of documentary evidence, including memoranda, board meeting minutes, and curriculum materials from different periods, that Gary Parsons made available to us. The electronic documents found on the ISP section of the school website, including downloadable copies of all ISP assignments, were also examined. Finally, there were two formal observations of current ISP teachers in their classes. It is worth noting our knowledge about ISP was further supplemented by other observations and encounters during the course of Larkin's student teacher supervision.

Brief follow-up interviews were conducted to make sense of the historical flow of events and to ensure the individuals, events, and institutions were being represented accurately. Drafts were shared with all of the interview subjects, and their feedback on the fidelity and verisimilitude of the case was sought and incorporated throughout the process of research and writing. Gary Parsons responded to the study noting, "I think you have accurately captured the essence of both the chronology of development and the philosophical goals of the program," (G. Parsons, personal communication, 7/28/2008). Similarly, Les Lombardi noted, "I think you caught the essence of the early years," (L. Lombardi, personal communication, 2/10/2008).

A persistent criticism of education research (e.g., Irvine, 2003) and social science research in general (e.g., Smith, 1999) is that it is often is done without consideration of its value to the subjects of the research, another outcome we explicitly sought to counter in our work. It is noteworthy that the teachers in our study reported this research was useful to them. Parsons and the current ISP teachers found value in the account in terms of their ongoing improvement efforts, while Lombardi noted its usefulness in portraying integrated science to other teachers in his professional development work.

To produce an authentic description of six teachers' practices within the context of a shared curriculum and the relationships within the school, district, and community setting, we have drawn upon the methodology of portraiture (Lawrence-Lightfoot & Davis, 1997) in three specific ways. First, we have chosen to ask, "What is right, here, and whether it is replicable, transportable to other environs?" (Lawrence-Lightfoot, 1983, p. 10). Second, we sought strike a balance between ethnography and journalistic observation to depict what Lawrence-Lightfoot and Davis (1997) refer to as "a view of the whole." We were not listening *to* a story, but listening *for* a story and became active participants in its construction. Finally, we attempt to give a thorough sense of the historical and physical context in which the teachers in this study have developed and sustained ISP. One way we do this is by offering a narrative description of the setting of ISP curriculum. This description of the context leading from the ''macro to the micro environment'' (Lawrence-Lightfoot & Davis, 1997, p. 61) involves the selection of important details designed to create a deeper understanding of the case. Strict adherence to portraiture methodology would entail a more emergent approach in identifying themes in the data. Still, we felt the framework identified by Halverson's (2004) phronetic narrative regarding affordances, constraints, and lessons learned would best shape an understanding of ISP as a sustained reform.

Review of the Literature

''Integrating'' curriculum has multiple meanings throughout the science education community and in a broader educational sense. In secondary schools, ''integrated'' curriculum may refer to aligning topics in a science course with those in other subjects (e.g., math or social studies) so students are exposed to similar curricular themes in multiple courses (Czerniak, Weber, Sandmann, & Ahern, 1999; Vars, 1991). Alternately, multiple disciplines may be merged into a single course with a particular focus such as the Science-Technology-Society courses made popular in the 1980s (DeBoer, 1991). In this study, the integration occurs between different science disciplines (e.g., biology, chemistry, physics, and earth science). Such integrated curriculum is distinct from what is often called general science because it has an intentional thematic nature, representing more than a collection of foundational topics. Examples of this sort of curriculum are well documented in science education literature (e.g., Brunkhorst, 1991; BSCS, 2000; Venville, Wallace, Rennie, & Malone, 1998).

In terms of science education reform, educational leadership often focuses on curriculum development (Bower, 2002), adapting pre-existing curriculum to local contexts (Barab & Luehmann, 2003), or scaling up curricular reforms through professional development (Loucks-Horsley, Hewson, Love, & Stiles, 1998). Loucks-Horsley et al. (1998) address general sustainability and implementation issues including the importance of shared visions, ample time, and developing capacity and leadership among teachers. A study by Roehrig, Kruse, and Kern (2007) noted the importance of leadership and collegial support in implementing a new science curriculum. Likewise, evidence suggests sustained and coherent efforts at professional development which are content-based and situated in classrooms have a positive impact on student learning in science (Banilower, Heck, & Weiss, 2007; Johnson, Kahle, & Fargo, 2007). Judson and Lawson (2007) describe a linkage between ''constructivist'' science teachers and professional networks within a science department, indicating that reform effort in science education may actually depend on more collaboration among teachers.

However, little research describes the practical wisdom regarding the context surrounding decisions educational leaders make to enact and sustain educational reforms. In fact, research from the late 1970s and early 1980s points specifically to the difficulties teachers faced in implementing externally developed curricular reforms like those supported by the National Science Foundation (e.g., BSCS Biology and PSSC Physics). Anderson (1994) notes, ''The reforms were found to be effective when used, but putting them into practice was much more difficult than anticipated'' (p. 62). Understanding why one particular reform could be implemented during this time period and sustained for 25 years becomes significant in light of other better-funded programs that did not fare as well.

The Setting and Context of ISP Curriculum

Six miles west of the city center, far enough from the lakes for roads to stay straight for reasonable distances, sits Lakeside Southwest High School (Southwest). Opened in 1966, it is Lakeside Metropolitan School District's (LMSD) most recently constructed high school. With a mall on the opposite corner and vast stretches of neighborhoods in every other direction, it is the most suburban in appearance of the district's five high schools. The parking lot is packed with student cars, and the few students one glimpses waiting for rides or arriving late are the exceptions that prove the rule—students do not wander the halls here. A ringing bell is all it takes for one to remember what walking through a building filled with 2,200 students looks and feels like.

Entering Southwest, visitors immediately get the sense that this is a busy school. Video monitors run announcements and scenes from upcoming plays, a display showcases Women's History Month with a dress in chains as a centerpiece, and an art gallery across the hall from the main office exhibits the colorful and moving work of a local painter. The office is a beehive of students, teachers, and people solving little problems and handing out parking passes and visitor tags without much more than a perfunctory glance.

The students in the halls appear racially and ethnically diverse and very nearly mirror the demographics of the district with 17% African American, 11% Asian, 8% Hispanic, 1% Native American, and 62% White[2] students. In the past two decades, the number of minority students at Southwest has tripled. Southwest's population of students characterized as low-income (28%) is slightly less than the district average (32%). Southwest also has similar student ratios in terms of individuals classified as special education (20%) and as English language learners (9%) as the district.

The school is large enough for ninth graders (and university researchers) to become easily disoriented, but it is more square than sprawling. Soon enough, one arrives at the second floor of the eastern end of the school where all of the science classrooms are located. A sign on a staff room door notifies students, "Knock once and wait." Upon entering, a visitor feels as if a doorway to a Saturday morning playhouse of science has just opened.

Inside what is affectionately known as the "bullpen," 12 desks hug the walls of the room, while another five are clustered in the center. A few teachers are sitting at their desks, grading papers or getting a quick bite to eat, but most are in their classrooms teaching. Star Wars posters, a mounted deer head, cases of various science textbooks, and mountains of fascinating personal science minutiae give the sense that if one had the run of the place, there would be a lifetime of interesting objects to examine.

On top of a file cabinet sits a computer playing an eclectic mix of music through stereo speakers. Upon asking, the researchers learn that each member of the Science Department has uploaded music onto the machine, which plays these songs randomly. This collective jukebox serves as a fitting metaphor of the collaborative spirit among Southwest's science teachers. A television monitor on the center desk displays a live image of the sink in the adjacent room, above which is a posted sign reading, "All it takes is one dish." There is no denying it—this would be an engaging group of people to have as colleagues.

It is fifth period on a Monday morning, and Cora Jackson's ninth-grade Integrated Science Program (ISP) class is just beginning. Alan Crane, another ISP teacher, is talking with Jackson in the front of the room. The students know him well. In fact, he had given an impromptu mini-lecture on the evidence for plate tectonics the previous Friday. He had been walking by the classroom when a student question prompted Jackson to "pull him in." Today, as Crane leaves and Jackson greets her class, Nick O'Malley, another ISP teacher, walks through from the back prep room with a box of springs. "Mind if I borrow these?" he asks, leaving before Jackson can answer him with a shushing wave. Jackson begins the class by soliciting questions from the students about Crane's talk. The first student to raise his hand asks about a theory he heard on a video that hypothesized everything on earth was made to "look old." Without dismissing the comment, Jackson keeps the focus of the questions on evidence of plate tectonics. Another student raises her hand and ponders aloud, "I was reading a reading and thought, what if there was more than one Pangaea? What if this wasn't the first time the continents had come together?"

"What if there was more than one Pangaea?" Jackson repeats, allowing the question to hang in the air for a moment. "Hannah," she answers, "Your idea is true." She then asks Hannah to remind the class about what Pangaea was, letting her talk as she represents continents using her hands, moving her palms around to the other side of an invisible globe. "That's a simplistic idea of what's happening, but it's what we believe," Jackson says. Another student asks if there would ever be enough new crust formed to stop the movement of the plates. "That leads nicely into this idea of the 'cracked earth'," she replies, "That's where we're going," transitioning seamlessly into the day's lesson.

In one corner of the class is a large flip chart by the Nystrom Company, showing the interior of the earth with the headline question, "What makes Earth the ever-changing planet?" It is a chart that one of the researchers has used in teaching his own high school classes. Later, in a discussion with Jackson about Fred Zimmer, one of the original architects of ISP in the early 1980s, she points to the chart, noting, "He helped design that chart, you know." Zimmer recently passed away, but his name continued to pop up as a revered mentor, valued colleague, and master teacher as we spoke to Southwest Science Department staff about the history of ISP. The chart serves as a reminder of the science teaching expertise of those who designed ISP as well as the deeply felt personal connections between the course's current teachers who sustain it with their continued collaboration.

The Design and Purposes of ISP

Since the mid-1980s, ninth-grade ISP has been the foundational science experience for most of the 600 ninth graders at Southwest. ISP integrates mathematics and various disciplines of science (i.e., physics, chemistry, biology, geology, and astronomy) by organizing units around the year-long theme of the first law of thermodynamics. Department Chair Gary Parsons described the group's rationale in the following way:

> The idea behind the course was that it would be nice for kids to think about their science education not as a list of facts or even as a list of science concepts, but to understand that there are just a very few overriding rules in the universe that seem never to be broken. The rule that that group picked was the first law of thermodynamics, which says energy is neither created nor destroyed. So could we take a look at it . . . from the point of view or the context of a variety of disciplines? So how would a biologist look at this law? How is it expressed in chemistry? How is it expressed in meteorology? How is it expressed in geology through plate tectonics? Astronomy? Well, before we knew it, we ended up with ten discrete units in Integrated Science, each coming at the conservation of energy law from a different discipline in science. (G. Parsons, interview, 3/23/06.)

A secondary goal of the designers of ISP was to help students develop reasoning and higher order thinking skills through cross-discipline integration of content. Furthermore, there were broad goals in terms of acclimatization to high school, in Parsons' terms, "training the eighth-grader to be a tenth-grader," (G. Parsons, interview, 3/23/06). Providing freshmen with the opportunity to master study skills was deemed integral to the effort to get them to think scientifically, take more science classes, and generally enjoy doing science.

Starting ISP

For a period of more than 20 years, the designers implemented and accessed various strategies and resources to meet their goals. Some influential factors were the historical circumstances of the school context. Southwest has a well-deserved reputation for innovation among Lakeside's high schools. The year before it opened, its principal was given the task of assembling a staff drawn largely from other district schools, what one of our interviewees referred to as "cherry-picking." Many imaginative and energetic teachers opted to join Southwest's faculty because working in an environment where creative approaches to education were encouraged was an attractive option, especially in the mid-1960s. Lombardi describes in its opening years, Southwest was "an electrifying place." The initial staffing gave rise to an informal, but faithfully adhered to, policy of allowing teachers input on new hires within their department. "While I was department head, there was never a person hired who I didn't strongly recommend," Lombardi explained (interview, 4/17/06). This practice strongly influenced the composition of Southwest's Science Department over the coming decades. The school culture of valuing teachers' opinions and knowledge is a resource in itself.

In the late 1970s, members of the Southwest Science Department began a series of informal staff gatherings at the house of Les Lombardi, the Science Department Chair, "with copious amounts of wine," Lombardi recalls. Lombardi described these meetings as, "philosophical discussions about what could be. We would fight—respectfully—and I was trying to push for more student-centered approaches and less content," (L. Lombardi, interview, 4/17/06). Robertson (2007) suggests students ultimately benefit from the collaboration that accompanies the "arduous" development of a shared vision in science education.

As a result of continuing discussions, the Science Department set three goals:

1. To have students take a lot of science classes.
2. To have 80% of seniors who spend 4 years at Southwest take physics.
3. To get students to love science and look forward to science classes beyond ISP.

One outcome of these discussions was to reform the traditional sequence of biology and chemistry during students' first 2 years of high school into a series of mini-courses, each 6 weeks in length. These 16 mini-courses were developed as a means to teach science in the context of a topic of high interest to students, also recognizing that giving students some choice over their own studies increased student investment in learning. The Science Department offered a 6-week introduction to aviation, meteorology, botany, nature photography, and animal psychology, among other topics. According to Lombardi and others, students responded well to the mini-courses. Teachers enjoyed them as well because the mini-courses played to their own strengths and interests. Scheduling issues continued to pose difficulties after the initial implementation, so the mini-course program eventually developed into one where sophomores took a semester of mini-courses, followed by a more traditional semester of biology.

The group continued to puzzle over ways to capitalize on the benefits of the mini-courses while responding to the pragmatic demands of class scheduling. Gradually, the idea for the ISP curriculum emerged out of the mini-courses concept. In developing the new ISP course, the teachers intentionally addressed concerns ninth graders had coming into high school. To begin, Lombardi and others surveyed a number of incoming freshmen and found their greatest concerns were: "Will the teacher like me?," "Will I succeed?," and "Will I get lost?" Further, it was decided if ISP was going to be the foundational course from which students would go on to other science courses at Southwest, then students should be taught organizational and study skills alongside science skills and processes.

The main group of science teachers responsible for authorship of the original artifact included Lombardi and Zimmer, among others. Parsons described the people in the group as articulate, persuasive, and very politically savvy. At the time, the faculty group had a good working relationship and experience creating and offering a distinct curriculum as a result of the mini-course program. Their primary goal was to offer a new, more integrated way of preparing students for learning science.

ISP was first taught as a one-semester, five-unit course from 1982 to 1984. During that time, it became clear the scheduling issues surrounding the mini-courses were problematic. As a result, the ISP curriculum was refined and the program expanded to a full-year, replacing the mini-courses.

Getting ISP off the ground took a great deal of preparation at the school, district, and community levels. At the time, Science Department Chair and teacher, Les Lombardi, had to go to the Department of Public Instruction (DPI) and verify each teacher's individual certification and licensure enabled him or her to teach ISP. Gary Parsons recounted, "We [Southwest] needed a policy change by the state agency in order to do this [ISP]," (G. Parsons, interview, 3/23/06). What resulted was through Southwest's good relations with the DPI, Lombardi was able to obtain a letter specifying as long as qualified teachers were present in the development of ISP, Southwest could have its science teachers teach ISP regardless of their particular field of certification.

From ISP's inception, the principals at Southwest were supportive of their science teachers who wanted to work at writing the new curriculum. However, one difficulty in the acceptance of the new program occurred where the planners least expected it—the community. Parents were concerned that their children were guinea pigs for this new curriculum, and they might fall behind students in other LMSD high schools using the traditional ninth grade science curriculum. Teacher Alan Crane, who was present at the development of ISP, pointed out the effectiveness of Les Lombardi's public relations efforts in this regard. Through various outreach methods, parental support for ISP steadily grew. Today, even with the course well established at Southwest, ISP teachers find themselves doing the similar types of public relations work to educate each incoming group of freshmen and their parents.

In the early years, Les Lombardi utilized some rather unorthodox ways to publicize and educate people about ISP. Lombardi made sure ISP students regularly entered science fairs and contests such as the Westinghouse (now Intel) Science Talent Search. When ISP students regularly won awards at these competitions, Lombardi would work to make sure it got coverage in the local newspapers or on television newscasts. He made sure the teachers went to conferences and/or delivered papers on ISP. In doing so, the teachers also won awards, which Lombardi ensured received press coverage. Alan Crane recalls, "It was pretty much unremitting, unrelenting effort for a long time so that people were convinced that, 'Oh Southwest, that's the science high school'," (A. Crane, interview, 4/3/06). The school also won a record three awards from the National Science Teachers Association's Search for Excellence in Science Education. Lombardi admitted he had set the goal of having each science teacher's name from Southwest in the newspaper every year. When one newspaper editor expressed concern over how much press Southwest was receiving, Lombardi actually started to feed the newspaper stories about other high schools in the district to balance the coverage. He also assembled fact sheets for local realtors to hand out to prospective homebuyers that included information about the innovations in science education occurring at Southwest.

Refining the Curriculum

During the development of ISP, the curricular design discussions centered on which units to include and how much time to spend on each unit. Since then, ISP curriculum has remained largely intact, true to its original purposes. Present curricular discussions revolve around how to best refine the syllabus and course materials including tests. Half of each test is standardized between all ISP teachers, while the remaining half is written by individual teachers for their classes. Crane explained the current goal is improving the specifics of the curriculum. He offers the following example:

> A colleague and I were arguing over how we are going to present the design of the filament, and does the question on the exam we just finished do that well? I was saying that it wasn't a very good question because some of the students missed it, and he's saying it was a good question because it relates to a fuse. (A. Crane, interview, 4/3/06.)

As in the above example, such refinements are now taken on by a small group of teachers who notice the need and then share the modifications with the rest of the ISP teachers.

A number of challenges and subsequent refinements of ISP curriculum have occurred over the past 20 years. The timeline in Table 3 illustrates the nature of each. The first major change was shifting ISP from a half-year program to a full-year program in 1985, and biology returned as a full-year, tenth-grade course. Many of the ISP designers viewed this as a natural progression of the original plan.

In 1992, a school-wide program known as CORE began at Southwest. In this program, groups of 80–90 ninth graders share teams of common English, Social Studies, and Science teachers. According to the school's data sheet, the purpose of the CORE program is "to make Southwest a smaller, more intimate, user-friendly place." The change in the overall organization of the ninth-grade experience actually complemented existing ISP structures quite well. Each ISP teacher is assigned three ISP classes consisting of students from the same CORE. These three classes are scheduled consecutively, either in the morning or in the afternoon, in dedicated ISP classrooms. As a result, each room is shared by two ISP teachers, one of whom sets up

Table 3
Timeline for the development of the integrated science program

Year	Event
1981	Planning for ISP (LL, FZ, and many others)
	Freshmen surveys
	AC completed student teaching
1982	First year of ISP with 5 units
	Mini-courses begin
1983	GP hired
1985	LL retired
1986	ISP changed from half-year to full-year ISP with 10 units
	Mini-courses ended
1990	BS hired after student teaching under FZ
1992	CORE program began
1995	CK hired
	First ISP unit split into 2 units due to students' "rough start" in ISP
1996	CJ hired
	"Tightened up" vocabulary in handouts
1997	NO hired after student teaching under FZ
1998	Common ISP planning time ended
1999	Most materials became available in Braille
	FZ retired
2000	Reading specialist helped review and adjust ISP readings
	Chemistry curriculum rewritten to adjust for topics covered in ISP
2001	ISP changed to 11 units
2002	Changed last unit to teacher's choice
2004	Developed web site
2006	CJ works with the district curriculum office to organize ISP materials into packets

labs and activities in the morning. The afternoon teacher is responsible for breaking down labs and putting materials away at the end of the day. Shared tasks contribute to the overall sense of distributed responsibility in ISP.

In 1995, the ISP team faced a new challenge. Parents and the district exerted pressure because some students were having a ''rough start'' in ISP. (G. Parsons, interview, 3/23/06.) Gary Parsons noted that in comparison to other subjects such as math and social studies, the gap between the types of science experiences students had in middle school compared with those in high school had widened. Many of the teachers in this study saw hiring trends at the middle school level that favored elementary generalist certifications over those specializing in science as one explanation for this rough start. The ISP teachers also suggested the changing demographics of the district as another reason. The implication was pedagogies that had worked well for Southwest's historically predominant white and middle-class population were not working so well with the increasing numbers of minority and working-class students. ISP teachers eventually responded by dividing the introductory unit into two distinct units to ease this transition. This change necessitated further revisions in the curriculum to make room for the extra unit. Doing so addressed the ''rough start'' issue and appeared to relieve the external pressure. Similarly, the majority of the new challenges ISP would face in the coming decade would deal with recognizing and responding to equity issues arising within the foundational task of teaching for scientific understanding and developing an appreciation for the nature of scientific practice.

In 1996, ISP teacher Brent Stetson undertook the task of what he called ''tightening up'' the vocabulary in the ISP handouts. After noticing many of the biology handouts contained a higher quantity of technical and scientific language than those from the physical sciences, he went through each of the handouts to ensure the quality of scientific language consistent across disciplines. Four years later in a manner of accommodation strategy similar to that described in Siegel (2007), Stetson worked with a reading specialist to tackle the handouts again, this time to ensure an appropriate reading level for all students. In both cases, substantial changes were made to course materials. Interestingly, during that same year, Southwest's chemistry teachers modified their own curriculum by dropping some foundational topics and adding a unit in nanotechnology. They recognized ISP was preparing their students well enough to enable such a change.

In 1998, due to time pressures at Southwest (notably the shared CORE planning periods), the ISP team lost common planning time. As a result, much of the present communication between ISP teachers occurs informally. They let each other know where they are in relation to the schedule or if they have any equipment or programmatic needs. Before 1998, one of the ISP teachers served as a team leader. In contrast, today's team of ISP teachers uses a more distributed approach to leadership, and all share responsibility for the tasks necessary to keep ISP running. Cora Jackson works with handouts, Alan Crane and Brent Stetson work with tests, Nick O'Malley works with lab materials and website maintenance, and Gary Parsons and Carolyn Kaiser have taken on various administrative responsibilities.

Cora Jackson is also working with district personnel to further revise the presentation of ISP curriculum. Rather than the current practice of using individual handouts, in the coming year, the handouts will be published as unit packets. Southwest's art students have been enlisted to illustrate the packets. In Jackson's words, one of the purposes is to make the presentation of ISP materials developed over the years ''look more official.'' (C. Jackson, interview, 4/3/06.)

Current Challenges: Student Preparation and Equity Issues

While the curriculum has been largely unchanged in terms of the units and nature of the course for a number of years, the ISP teachers we interviewed for this study stressed their biggest concern was the increasing numbers of students who do not come to school with sufficient preparation in science or math to meet the demands of the ISP curriculum. Veteran teachers explained that more and more students each year arrive less prepared compared with the students of 20 years ago. They are quite aware of the clichéd nature of such remarks. Even teachers of shorter tenure have remarked on a trend over the last eight years toward declining skills and work habits.

As the teachers we interviewed detailed the challenges they face in teaching ISP to students of all abilities, use of the phrase ''bimodal curve'' recurred. As an example of this, Alan Crane commented that he often reviewed the individual reading scores of students in his class, and they ranged from third-grade to postsecondary reading levels. Nick O'Malley, one of the newer ISP teachers, described a similar problem with mathematics preparation this way:

> One of the biggest things I've found over the last eight years . . . is I've noticed that the kids coming in out of the middle school, as far as their basic math prep, are far worse. Whereas when I started, we could manipulate equations and talk really about the math description of the science. The kids are not nearly as able to do that as they used to be. (N. O'Malley, interview, 4/3/06.)

Current ISP teachers say the central challenge they face is figuring out how to respond to students' needs without sacrificing the essential character of the course. ISP teachers describe themselves as being unwilling to change the content of their curriculum. In their eyes, lowering the bar of expectations and watering down the rich content to deal with the lack of student preparation defeats the original intention of ISP. Instead, they work to find ways to teach the same syllabus and build students up along the way in the areas they are now less prepared in. ''We dance faster,'' says Gary Parsons (interview, 3/23/06). ISP teachers described ''lunch bunches,'' where students and ISP teachers eat and ''do'' ISP (i.e., make-up labs, review handouts, give extra help for those who are struggling, etc.) In addition, ISP staff pride themselves on being one big ''family,'' frequently mentioning how they ''crash'' study halls, looking for ISP students in need of help, whether they are in their own or someone else's class.

Another concern of ISP teachers is the decrease in the number of students enrolling in ISP each year. This is not reflective of a drop in total number of students, reported the teachers. Rather, it reflects an increase in the total number of students identified as needing special education services, who for reasons detailed below are often not placed in ISP.

To understand this change, one must look at the changing context of special education services in the United States at the school and district levels and at larger state and national levels over the past three decades. The definition of what constitutes a student needing special education services and the implications of various special education labels and the nature of such services has been anything but static (Gallego, Durán, & Reyes, 2006). As categories for special education proliferated in the 1980s and 1990s, special education students considered able to function in classes with the larger student population were ''mainstreamed,'' while students considered to need extra support were segregated and placed in smaller ''pullout'' classes where the subject matter could be engaged at a slower pace with more resources. The original design of ISP was consistent with this model. Students who could function in ISP were placed in it, while those who could not—mostly students with special education labels—were placed in a less rigorous class where they could receive extra support.

Over the past decade, fundamental notions about the education of students with special needs changed, primarily because segregated classes came to be seen as detrimental (Capper, Frattura, & Keyes, 2000). In an approach commonly referred to as the ''inclusion model,'' students with special education labels are considered functional in ''mainstream'' classes if they receive support in those classes and are not segregated from their peers.

Lakeside Metropolitan School District has adopted the position that classrooms should be inclusive, as opposed to segregated, and instruction should be differentiated for a variety of student abilities within heterogeneous classes. However, this has been difficult to enact at the high school level due to a combination of budget cuts and vocal community groups who feel such an approach waters down resources that could be directed toward ''talented and gifted'' students. Southwest finds itself very much in the middle of this debate. The old mainstreaming model is in place structurally. Science teachers are willing, but struggling, to address the needs of all of their ninth-grade ISP students. Further, because minority students in the U.S. are often over-identified as needing special education services (Losen & Orfield, 2002), recent demographic shifts in the district have likely increased the total numbers of special education students. All of these factors contribute toward the trend of fewer students being placed in ISP. Although more special education students take ISP than in the past, the salient point is there are even greater numbers of special education students *not* taking ISP.

Currently, there are roughly 550 ninth graders in ISP and 100 ninth graders in another, less rigorous ''fundamentals of biology'' course. Nick O'Malley reports the following with regard to special education at Southwest. In the past, if a student had an Individualized Education Plan (IEP) on file, it used to mean he or she would not take ISP or sometimes freshman science at all. In discussing how Southwest's approach to special education has changed, O'Malley notes, ''Up until this point, it's been a blanket decision, 'Oh they're special ed. They don't take science.' We're starting to get to the point where they're realizing that some of these kids can do it, and they've supported my class as an experiment.'' He notes the implications of this approach with regard to mandated tenth-grade state testing in science, ''If the students don't take science their freshman year, they'll not do as well as those who did,'' (N. O'Malley, interview, 4/3/06).

One of Southwest's attempts to move toward a more inclusive approach has been using the CORE structure to focus resources on students who require them. Presently there are two CORE groups including students with special needs, a structure O'Malley notes has helped to place more special education students in ISP. Though many students are placed in the fundamentals of biology class instead of ISP, teachers see this as a pragmatic trade-off. ''I would like to have them in ISP for sure because I think they would get a lot out of it,'' Crane said. ''Seeing the numbers of people not taking science their freshmen year at our school, I think our first step is to get them into science period.'' (A. Crane, interview, 4/3/06.) The original philosophical group's goal of having all Southwest students take as much science as possible supersedes the goal of having as many freshmen as possible take ISP.

It is important to note that ISP teachers do not appear to exert the same influence over student schedules or special education placement as they do over their own curriculum. O'Malley notes ISP is designed for teaching both high school skills and science in heterogeneous groups. He refers to the placement and decision making process as he discusses why more students could be placed in ISP:

> I hate grouping kids based on certain aspects—whether that's special ed or anything else. But we have a tailor-made program able to do powerful stuff, and I don't think we're utilizing it as well as we can. And that's basically beyond the Science Department's control. Those are decisions that other people make . . . We have to figure out what we're going to do with those students who somebody deems not capable enough to do our class. And that's a big question I have also. Who decides that? It's not me. (N. O'Malley, interview, 4/3/06.)

One teacher, who has previously taught ISP, the fundamentals of biology class, and another multi-grade general science class spoke to the benefits of retaining options for some ninth grade students:

> There are smarter kids for emotional reasons, emotional disturbances, incarcerations, in-and-out of boot camp, in-and-out of jail, and stuff like that who do not have the best behaviors, who need to have a smaller setting and a slower pace for those reasons as well. You know, if I have a kid that's incarcerated for a week or two, because there are two of us and because we are going at a slower pace, we can probably get him caught back up. ISP is going to be varied. And that's not knocking ISP. You can only slow down so much, you can only accommodate so much. (H. T., interview, 4/3/06.)

Even though more special education students are entering ISP, as the numbers of special education students climb, ISP teachers question what happens when the ratio falls to 450 students in ISP and 200 students in the other course? What happens when there are 350 students in ISP and 300 in fundamentals of biology? ISP teachers are concerned that by not changing ISP curriculum, they will keep students out. At what point could ISP become unsustainable? And what could be done to slow or prevent that? It remains to be seen if those currently working with ISP can address equity challenges as effectively as the committed group of teachers who faced the philosophical challenge of planning the curriculum 25 years ago.

Analysis

This analysis draws upon Halverson's (2004) discussion of the use of phronetic narrative to capture practical wisdom in the professional practice of educational leaders by focusing on three areas of interest: affordances of the artifact, constraints on action, and lessons learned from the process. *Affordances* are desired consequences a particular artifact enables. An educational leader may or may not choose to take advantage of all affordances an artifact offers, and over time, the results of these affordances may become resources for further redesign of the artifact. These affordances ''reflect an actor's assumptions of how an artifact might be used in a local context.'' (Halverson, 2004, p.19) The *constraints* are features of the context requiring certain design choices for the artifact to be either necessary or excluded. Educational leaders adjust what they want and know from how they perceive a situation's constraints and from how they perceive the nature of the particular problem to be solved. The *lessons learned* from a particular artifact represent an embodiment of the practical wisdom of the artifact designers in light of the affordances and constraints. These lessons go beyond simple descriptions of the artifact, seeking to access explanations for why events unfold in a particular manner. Each of these aspects of practical wisdom is examined in detail below with regard to ISP.

Affordances

At the level of the individual student, ISP provides a unique structure in terms of the study skills and science learning that can be built upon in subsequent experiences. Teachers across the school are aware of the efforts of ISP teachers in "training the eighth grader to be a tenth grader." Thus, ISP teachers intentionally seek to socialize students into Southwest's school culture in specific ways. ISP also provides the opportunity to practice key high school skills in context (i.e., studying, taking notes, graphing, etc.). Additionally, the heterogeneous nature of the course has recently allowed for a stronger inclusion effort to support students with special needs.

In terms of science teaching and learning, freshmen receive quality instruction from active and fully engaged veteran teachers. Also notable is the alignment of ISP with state and national standards resulting from a less fragmented approach to science instruction. ISP teachers claim students gain a deeper understanding of science concepts and knowledge about the nature and processes of science. They also point to the high number of students taking 4 years of science as evidence that ISP helps to foster student interest in other science courses at Southwest.

Furthermore, ISP allows students to experience the teaching styles of multiple teachers through study hall crash sessions, lunch bunches, and guest lectures by other ISP teachers. By sharing a common curriculum and a philosophical outlook toward the learning of science, ISP teachers are able to assist more students outside of class than they might otherwise. Students from different ISP sections share a cohesive science experience in ISP, but not at the expense of teacher individuality. While individual teachers may teach the same concepts in drastically different ways, the overall learning goals of the course remain consistent across teachers.

An additional affordance related to teacher autonomy is the way unit tests are designed. Half of each test is common to all ISP teachers, while the other half is specifically designed by individual teachers to represent the material as it was covered in her or his particular class. Similarly, the content of the final ISP unit is not shared, and individual teachers are free to design it to meet their own interests and strengths. Gary Parsons notes the final ISP unit is a vestigial remnant of the original mini-courses from over 25 years ago.

In terms of Southwest's Science Department, the primary affordance relates to the shared obligations and common language of ISP teachers. They continue to provide opportunities to create trust among one another. This has been clearly shown by Bryk and Schneider (2002) to be an organizational condition needed for improvements to occur. Common activities and assessments allow for group input into adjustments of ISP. ISP's distributed leadership pattern allows for the efficient division of tasks such as photocopying, test writing, and preparing laboratory materials and equipment. Furthermore, the strong departmental tradition of teacher influence in the hiring process allows new teachers to be carefully selected and subsequently socialized into the "philosophical group," allowing group norms to be perpetuated. The normalization of such an innovative program over time allows teachers to maintain confidence in the sustainability of the program.

As a common ninth-grade curriculum, ISP allows teachers and administrators to present a clearer picture, both to the district and to the public, regarding science education at Southwest. Southwest's CORE program complements ISP, allowing teachers greater access to knowledge about individual students. Availability of ISP curriculum materials on the ISP website has practical and public value. Students may access course materials from outside of school, and parents, guardians, and community members have a window into an otherwise inaccessible aspect of children's school experiences in science. Such availability fosters a sense of accountability to the community and increases the status of the Science Department, and Southwest by extension, in the public eye.

Constraints

The designers of ISP were limited in design choices in two primary ways. The first constraint consisted of limitations placed on the design as a result of available resources or necessary structural requirements. We designate these *pragmatic constraints*. The second and more numerous type we call *philosophical constraints* because these limitations were self-imposed by the "philosophical group." These were essentially the nonnegotiable features they felt ISP ought to have. To transgress these would have severely stressed the professional community existing around the problems the philosophical group sought to solve.

Pragmatic Constraints. Without time for in-school meetings to develop curriculum, informal meetings were held at the Science Department Chair's house. Teachers were not working within a budget and were not compensated for their time. Additionally, they were "starting from scratch" because at the time, no program existed like the one they envisioned. Southwest's resources were limited, and the final product needed to be crafted to fit the structural elements of the school. As the ISP planning progressed, it became clear certification issues could surface and preparing for dealing with them became part of the overall plan. Once the specifics of the curriculum solidified, the concerns that not everyone would want to teach it and achieving a consensus among the teachers who would teach ISP became important.

Later, two significant pragmatic constraints became important to ISP teachers. The first was the perceived change in student readiness to engage in the curriculum as originally designed. The second constraint was the combination of changing special education policies and school demographics. Together, these two constraints transformed the nature of the problem set by the original ISP designers. Whereas the original problem was designing an effective way to teach science, the new problem became how to teach science effectively to a diverse student population. One could argue both problems existed all along, but the need to better serve marginalized students within ISP was pushed to the forefront by external factors such as demographic shifts in the school, district equity initiatives, and quite likely, reporting requirements of the No Child Left Behind legislation (United States Department of Education, 2002) that mandates the disaggregation of test scores by distinct categories such as race, income level, and special education status.

Philosophical Constraints. In the early 1980s, the target students for initial ISP efforts were ninth-grade students who took biology as their first high school science course. The needs of ninth-grade and, at times, tenth-grade students were the focus of planning for the mini-courses and later ISP. The constraint of de-tracked, heterogeneous groups was a conscious choice of the designers, and the structure remains that way *within* ISP classes today.

As ISP design progressed from a semester course followed by mini-courses to a full year of ISP, the philosophical choice to include as many science disciplines as possible pared down to the number of topics that could be focused around a central idea in physics. This led to the constraint of less coverage in individual disciplines, excluding many favorite activities developed by teachers over the years. However, the decision to use common activities and assessments also meant more consistent instruction across classes.

Lessons Learned

An examination of the origins and subsequent modifications of ISP draws attention to aspects of curriculum implementation and reform that might be otherwise overlooked in a description of the program as it now exists. First, the importance of the original Science Department and the continuing departmental influence in staff hiring decisions cannot be overstated. Over its history, ISP teachers and Southwest's Science Department have placed great importance on control over the entry of new members into the "philosophical group," a practice directly affecting the way ISP was developed and sustained. The continuity of staff teaching ISP over the years is closely correlated. Two of the six teachers teaching ISP over the past 25 years have been involved for more than 20 years, while the two others did their student teaching in ISP classes at Southwest with Fred Zimmer, one of the original designers.

Another lesson can be found in the similarities between the ISP teachers' curricular emphasis on evidence for scientific concepts and their own use of evidence to analyze their curriculum. From the freshman biology tests given to seniors in the early 1980s which demonstrated the need for a program like ISP to the common assessments ISP teachers currently use, data-driven decision-making is an integral part of the program. Additionally, while many other reforms direct attention to the needs of the ninth grader (e.g., Wang & Allen, 2003), this study shows how socialization efforts can be implemented in a specific content area.

The importance of considering local and state policy issues in planning is another lesson learned. Administrative support certainly helped ISP in the beginning by working within the loose boundaries of district science structures. In particular, the anticipation of possible certification issues by the original designers seems quite prescient. At any point, an overzealous bureaucrat could have derailed the whole program had it not been for the designers' foresight to get a waiver.

When teachers are presented with a program such as ISP, where teachers' classes are closely synchronized with common assessments and activities, a typical reaction might be to presume this sort of environment is one that de-skills teachers, reducing them to deliverers of curriculum (Apple, 1993). At Southwest, ISP presents a powerful counterargument. The common assessments and activities actually operate as elements allowing teachers to speak a common language, teach each other's classes, reflect critically about what they do as a professional community, and distribute leadership tasks. ISP teachers are still able to take advantage of their personal strengths and employ their own pedagogical approaches to implement the curriculum. Furthermore, this approach allows for consistency in the philosophical design of the course. These are hardly features of de-skilled teaching, and ISP demonstrates common curriculum need not be so.

Discussion

At first glance, ISP may appear to simply be an interesting way of organizing a ninth-grade general science course. Nonetheless, it stands as a philosophically grounded and time-tested artifact, fitting many notions of what current science standards suggest an inquiry-based, introductory high school science course ought to look like (American Association for the Advancement of Science, 1989; National Research Council, 1996). Through daily interactions with their students, science teachers at Southwest feel ISP works. They note over 80% of Southwest students *do* take four years of science, including physics, and present this as evidence for satisfying one of the original goals of the planners. Given these outcomes, it is worthwhile to examine how the development and continuation of ISP relates to current knowledge about inquiry-oriented science education reform and general educational change.

The literature on inquiry-oriented science education reform is consistent on a number of points. First, the implementation of inquiry curriculum depends greatly on what occurs at the level of the individual school as well as within wider district and state contexts (Roehrig et al., 2007). The second is translating advocacy for inquiry into classroom practice is challenging (Lewis, 2006) and often takes considerable time and effort (Loucks-Horsley et al., 1998). Last, the success of such reforms relies on a system of shared goals within a professional community oriented toward collaboration, as opposed to isolation (Bell, 2005; Bell & Gilbert, 1996; Khourey-Bowers, Dinko, & Hart, 2005). All of these findings are consistent with the story of ISP.

Anderson (2007) lists five common teacher dilemmas identified from his work developing case studies of inquiry-oriented science education reform. He describes these dilemmas as "situations in which all of the alternative actions available seem to have undesirable consequences, along with what is desired" (p. 816). Examining ISP in light of these dilemmas is fruitful because the first four have been resolved in ways ultimately strengthening student learning. The fifth is clearly still being wrestled with, and it is not clear whether it can be resolved without going back and making significant changes to dilemmas previously considered settled.

Dilemma 1: Time

An inquiry approach to science teaching entails making clear curricular choices about what will and will not be included in a particular science course. Many teachers often feel strongly about topics threatened to be sacrificed in such an effort. ISP designers faced this dilemma early on. While favorite topics remained initially in the mini-courses, eventually teachers became convinced that paring down curriculum to make room for inquiry was a greater benefit than what could be gained by covering more content.

Dilemma 2: Ideal Versus Reality

Anderson notes that science teachers generally view the portrayal of standards-based science teaching to be "in conflict with the realities of the classroom" (p. 816), a problem that Kennedy (2005) has also identified in general reform efforts. As the designers of the curriculum, ISP teachers were not trying to adapt someone else's vision to their day-to-day teaching. Rather, they were starting with their reality and constructing their own vision of what they wanted their students to experience in learning science. In this case, the resolution of this dilemma resides in recognizing the value of the knowledge teachers are able to generate when they inquire into their own practice (Cochran-Smith & Lytle, 1992; Zeichner, 2001).

Dilemma 3: Changing Roles and Work

The collaborative nature of Southwest's teachers in the design and implementation of ISP and the continued distribution of tasks and leadership responsibilities signal a shift in traditional teacher roles. A philosophy of teaching where teachers are isolated individuals responsible only for their own students falls short of what is needed in a curriculum like ISP.

Dilemma 4: The Preparation Ethic

Many school cultures are permeated with the notion that the purpose of learning science is to prepare for the next level of learning science. This implies an inquiry approach to learning science will leave students unprepared for future courses. By contrast, ISP designers believed an understanding of inquiry *is* the preparation students need along with organizational and study skills to be successful in future science endeavors.

Dilemma 5: Equity

Anderson (2007) asks "What does it mean to teach science to all?" He bluntly notes, "Many teachers see a tension between providing a strong education for the able and willing students and at the same time providing for the uninterested or less able students" (p. 817). Current ISP teachers struggle with this issue. It has become clear that their particular model of science teaching and learning works for many students, but does not work for others. There is little disagreement about the racialized nature of the "bimodal" curve referred to earlier. There *is* a stark achievement gap [or in Ladson-Billings' (2006) terms, an "education debt"] at Southwest, as well as in Lakeside Metropolitan School District, between white students and students of color in all tested high school disciplines, including science. The state in which Southwest is located was recently reported to have the highest fourth- and eighth-grade reading achievement gap by race in the nation (National Center for Education Statistics, 2007). Attempts to address these disparities are an ongoing focus of building-level reforms and district-wide professional development efforts. Both have become politically sensitive matters with the general public in the local community. Now highlighted by disaggregated test scores, the resolution of this dilemma will likely determine whether or not ISP survives another 25 years.

It is worth examining briefly how the findings of this study connect to the larger issue of educational reform. In a broader and more comprehensive look at educational change based on empirical studies of school reform, Fullan (2007) lists ten elements necessary for educational change. These elements include:

1. Define closing the gap [between high and low achievers] as the overarching goal.
2. Attend initially to the three basics of literacy, numeracy, and the well-being of students.
3. Be driven by tapping into people's dignity and sense of respect.
4. Ensure the best people are working on the problem.
5. Recognize all successful strategies are socially based and action oriented-change by doing rather than change by elaborate planning.
6. Assume lack of capacity is the initial problem and then work on it continuously.
7. Stay the course through continuity of good direction by leveraging leadership.
8. Build internal accountability linked to external accountability.
9. Establish conditions for the evolution of public pressure.
10. Use the previous nine strategies to build public confidence (p. 37).

It is striking to see how closely this list fits the development and sustenance of ISP over the past two decades as we have described it in this study. For example, attending to the well-being of ninth graders was an initial goal for the program, as was a shared conception of the purposes and outcomes of an introductory high school science course. It also worth pointing out that having classes taught by the most experienced teachers resonates with a numbers of items above, as does the manner in which teachers' capacity for collective efficacy and leadership is developed as they share program responsibilities.

Also noteworthy is the way ISP exists within a context of instructional program coherence (Newmann, Smith, Allensworth, & Bryk, 2001), another element identified as necessary for successful educational change. Instructional program coherence occurs when teachers are able to see how multiple reform efforts in a school complement one another, or at the very minimum, do not interfere or send mixed messages and disrupt the possibility of shared meaning. When the original group of Southwest science reformers designed the mini-courses in 1982, there was little instructional program coherence. The mini-courses did not fit well into the overall structure of the year-long school schedule, and the benefits gained from providing such a program could not overcome the logistical difficulties in sustaining it. Over time, as the program was reinvented as ISP to be more consistent with the basic structural operations of Southwest. Thus, it became easier for other school-level initiatives, most notably the CORE program, to maintain a better structural fit as they were implemented. One important aspect of ISP relating to this structural fit is ISP appears insulated from other ‘‘add-on’’ efforts commonly found in high schools. While well-intentioned, such add-ons might steer the ISP teachers away from their carefully crafted common curriculum.

One final discussion point relates to the way the ISP teachers appear to have overcome the isolated and individualistic view of teaching that many reformers describe as one of the most significant barriers to educational change (Elmore, 2002; Fullan, 2007; Stigler & Hiebert, 1999). The ISP teachers at Southwest appear to have invested their sense of professionalism in a collective autonomy, where the shared goals and common curricula supply the conditions for non-threatening discussions about pedagogy. ISP teachers are not isolated, due to both the physical proximity of science classrooms to one another as well as the actual sharing of classroom and preparation room space. Consequently, there are ample opportunities for interaction around shared goals.

Implications and Needed Research

ISP at Southwest is and always has been a teacher-driven reform effort. While it enjoys the support of school and district administration, without which it could not have survived so long, it is a program owned and operated by the teachers who believe in its goals and are committed to the continual refinement of their practice. Considering the history of science education reform over the past century (Anderson, 1994; DeBoer, 1991; Rudolph, 2002), it is hard to escape the conclusion that external efforts to change the way teachers teach science are often frustrated at the level of individual teachers, who modify curricula to meet situational needs in ways that may be at odds with the goals of such reforms. This was not an issue at Southwest because the efforts to change science teaching grew from the teachers’ own values and beliefs about the teaching and learning of science within a specific context. In the beginning, these views took shape and were strengthened as teachers developed shared meaning around them and they eventually became part of the Science Department’s culture. This study reaffirms the importance of placing the values and beliefs of teachers at the center of educational reform, professional development, and teacher education (Crawford, 2007; Jones & Carter, 2007; Roehrig et al., 2007).

Another implication of this study relates to the hiring practices of districts and the issue of teacher turnover. It is no coincidence that highly qualified and motivated teachers would be found in a place with such an innovative curriculum or that they would be empowered to have such a high degree of control over hiring decisions. This raises the question of whether such a reform would be possible in school or district where teacher turnover rates were higher or hiring decisions were made regardless of how new teachers might fit in to the existing ‘‘philosophical group.’’ Supporting and empowering teachers on a departmental level—even just to generate evidence from their own practice to foster the necessary discussions about values and beliefs—might be effective in reform efforts and is worth further research. What this type of effort might look like in a school or district where it is more difficult to attract and retain highly qualified science teachers remains an important question. One avenue of potential research is a further inquiry into the relationship between teacher retention and department-level reform.

Finally, it is crucial that research on reforms in science education talk about and describe ‘‘standards’’ and ‘‘standardization’’ in a manner beyond the simplistic discourse on standardized testing. Teachers at Southwest have developed a more nuanced view of how to standardize a curriculum without compromising teacher autonomy, but it is surely not the only way.

We wish to thank the past and present teachers of ISP at Southwest for their assistance with this project and note Frank Zuerner’s deep and lasting impact on the lives of his colleagues and students. We also wish to thank Dr. Barbara Ryan Larkin for her multiple readings and helpful feedback on many versions of this article, and Dr. Richard Halverson for his encouragement and support in this project.

Notes

[1]The names of schools, the district, and individuals in this study are pseudonyms.

[2]These demographic labels are those used by the school district in its reporting documents.

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Appendix A

Integrated Science Program
Southwest High School
Unit 2; Handout No. 3

Name ______________________
Period __________ Date ______________
Teacher ______________________

LAB: CONDUCTION AND THE CONSERVATION LAW

Background:

In this lab activity, you will be studying **thermal energy** (normally referred to as "heat"). Thermal energy, or heat, is the energy possessed by a substance because of the **motion of the molecules** it contains.
Note: This is different than the kinetic energy **an object** possesses due to **its** large scale motion.

Thermal Energy (Heat) is the **total amount of kinetic energy** of a substance's molecules.

Thermometers measure the **average motion of the molecules** of a substance, NOT the total energy they possess as a whole. Molecules respond to the addition of thermal energy by speeding up, which in turn increases the average speed of all the molecules in the substance, which is a higher temperature!
A thermometer translates the average motion into numbers on a scale. If the thermometer indicates a temperature of 90 degrees, you know that on average the molecules are moving faster than if it indicates 40 degrees.

Notice that the addition of heat energy is not an increase in temperature but, can be a cause of an increase in temperature.

Temperature is the **average kinetic energy** of a substance's molecules.

Solids, Liquids and Gases:

A solid has a rigid shape because the molecules are locked into a pattern. If the solid is heated the speed of the molecules is increased. When they move fast enough they can break away from this rigid pattern. As this happens the solid melts and becomes a liquid.

In a liquid the molecules are held together by bonds that are loose and which are constantly changing from molecule to molecule. The molecules are "bonded" but not rigidly, thus liquid water has the ability to flow as it tends to stick together. If we add more heat to the liquid, the speed of the molecules increases and the temperature rises. Soon some of the molecules are moving fast enough to escape into the air as they completely overcome the bonds between the molecules. The liquid becomes a gas.

In a gas the molecules are not bonded to each other at all.

Removing heat causes an opposite effect.

STOP!! Answer these questions...

Which has a higher temperature, a cup of hot water or a bathtub full of cold water? ______________

Which has more heat, the cup of hot water or the tub of cold water? ______________

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Like most forms of energy, thermal energy (heat) can be **transferred** from one place to another.

In your house or apartment, the heat energy from the furnace is transferred to the rooms through heating ducts. Another example is a cup of boiling water. Heat transfers from the hot water to the cooler outside of the cup. If you touch the outside of the cup, you can feel the heat flowing into your hand, thus increasing its temperature.

In this lab activity you will study the basic concepts that explain how thermal energy (heat) can be transferred from one place to another. This lab allows you to measure the flow of heat energy as it is affected by many variables. Your measurements and data are critical to the building of realistic conclusions, so it is important to carefully follow the procedures as they are written.

Prediction Statement: (what question will you be answering through this study? What outcome do you expect to see? What patterns should you see in the data and graphs produced?)

Materials:

Two (2) insulated containers. Both containers MUST be the same size.
Two (2) lids with slots
One (1) metal (aluminum) transfer bar
Two (2) thermometers:
One (1) white plastic thermometer with a range of -20° C to 50° C
One (1) metal thermometer with a range of 20° C to 110° C
Hot water and cold water supply
Safety glasses
Graph paper, ruler and pencil

Laboratory Procedures (Day One):

****** Read all procedures before starting the lab ******

1. Insert the metal heat transfer bar and the thermometers into the lids of the containers so that the containers can be quickly sealed after the water has been added to them.
2. Put on your **safety** glasses.
3. Fill one container with **cold water** to a level about one inch from the top.
4. Fill the other container with **boiling water** to a level about one inch from the top.
5. Assemble the apparatus.
   NOTE: Put the lid with the plastic thermometer in the container containing **COLD WATER**.
   Put the lid with the metal thermometer in the container containing **HOT WATER**.
6. Record the starting temperature of the two containers in the data table.
   Note: Since the temperature of boiling water is ~98° C (in this room), this number is already recorded as the starting temperature for the container with the hot water.
7. Temperature readings for both containers should be taken every minute for a period of 30 minutes. Record the temperature readings in the data table provided.
8. At the end of the 30 minute period, take one last data reading then pour 50 mL of the hot water into a beaker. Immediately pour in 50 mL of cold water into the same beaker. Stir the mixed water for a few seconds, then take the temperature of the water. Clean up the lab station.
9. Construct a **graph** which shows how temperature change in **both** containers is dependent on the amount of time the energy transfer took place. If in doubt, review your handout on graphing skills. Be certain to plot the final data point collected immediately after mixing the two water samples.

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Laboratory Procedures (Day Two):

1. Design a method for testing the ability of various materials to conduct heat.
2. Record data that allows you to separate materials into two categories, insulators and conductors.
3. Be prepared to describe and defend your findings using the data as evidence.

Summary Questions: (Making deductions based on information)

Using the information (data) you collected during this lab activity, be prepared to answer questions like those provided below.

NOTE: Review the data, think about it, talk to your partner and others about your conclusions.

1. Is energy transfer taking place between the containers, in which direction did the energy flow, and what evidence supports your findings?
2. How does the energy get from one container to the other? (be very specific about the mechanism)
3. Is the slope of the graph greatest (steepest) during the initial or final readings?
4. Comparing any two moments in time during the lab, how does the rate of energy transfer compare to temperature difference between the containers?
5. Given enough time, would the lines on your graph come together and then cross? Explain carefully.
6. What is the relationship between thermal energy (heat) and temperature? Describe what they have in common and what sets them apart from each other.
7. Assuming that the volume of the source and the sink are identical, and made of the same material, heat lost must equal heat gained, this is the Conservation of Energy Law. The material in both containers was water in the same amount, thus the temperature increase of one cup should match the temperature decrease of the other cup. Did this occur? Explain - Why OR Why Not.
8. List things you might do to make energy lost more equal to energy gained between containers.
9. What is a variable? Why would you need to "control" a variable? What variables were controlled and uncontrolled in this lab?
10. Make a list of different ways you could improve this investigation. Explain how your variation of the experiment would affect the data that would be collected.
11. Compared to the temperature difference between the hot and cold water, what is the temperature of the mixed water? Why is this a predictable outcome?
12. What is the expected temperature if we mix…
    100 mL of 60 °C water and 50 mL of 30 °C water
    300 mL of 80 °C water and 100 mL of 40 °C water
13. How can you determine if a material is a good conductor or is an insulator?

Conclusion Statement:

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Appendix B: Interview Protocol

1. Tell us a little bit about yourself and your professional background.
2. Describe the Integrated Science Program (ISP) and how it operates in general at Southwest.
3. What is it like to teach with ISP (i.e., How do you use ISP in your work?)?
4. Is ISP useful to you? If so, why is it useful? If not, why not?
5. How did ISP develop in the school? When did you first learn of the ISP concept (i.e., professional development, school network, or other)?
6. People create tools like ISP to solve problems. What problem did or does ISP address?*
7. Why was this problem important to the school at that time?*
8. What was accomplished by addressing this problem?*
9. Who was involved in the development of ISP and why were they involved?*
10. Who is currently involved in using ISP?
11. What resources helped the school develop ISP? Were the resources available or cultivated?*
12. What hindered the development of ISP? How surmount those hindrances?*
13. How has ISP changed since it was first developed? If it has changed, why did it change and what influenced that change?*
14. What has been the effect of the artifact on student learning, teachers' or others' work, the district, community, etc.?
15. As a result of the ISP development process, what did you learn? How have you changed?
16. How do you see ISP changing, if at all, in the next few years?
17. What do you think will help/hinder this change?
18. Are the feeder schools, such as T. Middle or J. Middle, changing what they do to prepare students for ISP when they enter Southwest?
19. Who else should I talk to, supporters and detractors, about the development & use of ISP?

*These questions were only asked to those who were present at the time of the development of ISP.