Science Education and Culture: Inquiry-Based Learning

Dashia Magee & A.J. Meier

The College of New Jersey & University of Northern Iowa - USA

Abstract

At a time when inquiry-based science education is finding increased acceptance, US classrooms are exhibiting a significant increase in diversity. This necessitates attention to the compatibility between the culture of inquiry teaching and the broad range of cultures that form students' backgrounds. Although some research has considered students' cultural backgrounds and the roles these might play in the effectiveness of an inquiry approach, none has focused on the specific characteristics of an inquiry approach that might constitute cultural "biases" for a broad range of students with a concomitant broad range of cultural values and beliefs. This article seeks to identify characteristics of an inquiry approach, compare these to the potential cultures students may bring with them to the classroom, using cultural orientations as a heuristic, and suggest construals of inquiry that could better address the needs of a greater number of learners.

Keywords: Inquiry, Culture, Science Education, Communication, Learning

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Introduction

In an article in the *Wall Street Journal* at the beginning of 2006, Tomsho expressed concern about U.S. American high school students' comparatively low test scores on international science tests and questioned the benefits of current science curricula that place too much emphasis on inquiry-based learning, which entails students' engagement in hands-on, inductive problem-solving. While inquiry-based learning is not especially new in science education (cf. Abd-El-Khalick et al. 2004; Anderson 2002; DeBoer 1991), it has been increasingly embraced since 1996, when the *National Science Education Standards* (NRC) declared that "inquiry is central to science learning" (p. 2). Since then it has also received increased critical attention in scholarly research with attempts to define it, to identify its variously construed characteristics, its philosophical underpinnings, as well as its role in overall goals of science education, and to assess its effectiveness within science curricula.

Such considerations of inquiry-based science education are further complicated by the increasing diversity in the student population, whether this consists of non-dominant cultures, immigrants, refugees, or their offspring. Already in 2003, ethnic and racial minority students comprised 43% of the total public school population in the U.S. (U.S. Department of Education 2005). Students thus represent an increasingly diverse set of cultural backgrounds. These have not only informed the prior educational and home experiences of many students but also their assumptions and expectations about appropriate pedagogical practices. In line with constructivist learning theory (e.g., Wheatley 1991), what students bring to the learning context in terms of past experience and expectations plays a major role in their learning. A lack of fit between these experiences and expectations and those assumed in the classroom can significantly inhibit learning. In 1988, Ogunniyi alleged that science educators recognized the need to consider learners' cultures and worldviews in order to avoid potential conflict in science teaching that could adversely affect success in learning. The National Science Education Standards (NRC 1996) and Benchmarks in Science Education (AAAS 1993) similarly advocated the creation of inclusive science education, which encompasses all students, regardless of race, gender, nationality, and cultural background (AAAS 1993; NRC 1996). An inquiry-based approach was viewed as a way to achieve this. The National Science Foundation (NSF) (1998) also emphasized that different cultural perspectives should be incorporated in curriculum materials to make science accessible to all students. However, attention in the literature to the relationship between "all students" and the increasingly popular inquiry approach in terms of potential mismatches between cultural orientations has remained relatively

underdeveloped. Although some research has considered how students' cultural backgrounds play a role in the effectiveness of an inquiry approach in science education (e.g., Barba 1993; Fradd, Lee, Sutman, & Saxton 2001; Lee 2003; Lee & Fradd 1998; Lee & Fradd 2001), none has focused on the specific characteristics of an inquiry approach that might constitute cultural "biases" for a broad range of students with different cultural backgrounds.

This article seeks to address this relatively neglected and important area of inquiry-based science education by identifying its characteristics, evaluating their compatibility with students representing a diverse set of cultural orientations, and suggesting construals of an inquiry-based approach that could better address the needs of a greater number of learners in an attempt to prepare them to compete successfully in scientific endeavors globally.[1] As such, this paper importantly extends current scholarly considerations of a timely issue that affects a large population and provides useful directions for both pre-service and in-service teachers, as well as for teacher educators, in the quest to improve learning opportunities for a diverse student population.

A depiction of inquiry-based science education in the first section below will be followed by a brief review of relevant literature. The subsequent section will then investigate inquiry-based science education in terms of its dominant cultural orientations and possible incompatibilities with the potential cultural orientations of student populations. This provides the basis for suggestions of ways to adapt an inquiry approach to enhance science learning for all. The final section will address the important role teacher education plays in this endeavor.

Characteristics of an Inquiry-Based Approach

Students are diligently working on their science projects. One group is gathered around a computer, e-mailing its "scientist" from the local university. Another group is reading quietly in the "research corner," seeking information on their topic before planning an experiment. Other groups are scattered throughout the science laboratory, conducting self-designed experiments to verify or falsify their respective hypotheses. While the students are thus engaged, the teacher walks around the room, asking questions to help students clarify their ideas and guide them in their engagement in the scientific process.

The scene just depicted provides a glimpse of what may be described as a typical middle school or high school science classroom employing an inquiry approach. Although no unified depiction exists of how inquiry is to be implemented in the science classroom, general themes and variations on these themes can be identified. This section will attempt to do so by exploring the philosophical underpinnings of an inquiry approach, its definition, its goals, and the roles of teachers and students engaged in such an approach.

Philosophical Underpinnings

Inquiry is congruent with constructivist teaching ideology (Adams & Hamm 1998; Etheredge & Rudnitsky 2003; Llewellyn 2002), which emphasizes students' prior knowledge as the foundation of further learning (Llewellyn 2002). This calls for a type of scaffolding, in the Vygotskyan (1978) sense, that involves taking students from where they are and, with just the right amount of support from the teacher, guiding them to become more autonomous learners (McNary, Glasgow, & Hicks 2005). In science education, it is students' experience with the natural world that is viewed as forming the basis of their active engagement in attaining this understanding (Llewellyn 2002). However, another important aspect of students' prior experience involves their cultural backgrounds, which provide a lens through which the natural world is viewed and investigated and which may be incompatible with aspects of inquiry-based science education.

Defining Inquiry

The definitions found under the rubric of *inquiry* vary in complexity and design (Anderson 2002; Schwartz et al., 2004). Not surprisingly, in the world of science education, there is also not a current unified view of precisely how inquiry should be defined (Anderson 2002; Etheredge & Rudnitsky 2003; Schwartz, et al. 2004). Abd-El-Khalick et al. (2004), for example, identify no fewer than seven

dichotomies in the way inquiry has been characterized in various science curricula. Indeed, Colburn (2000) assesses its definition as "the most confusing thing about inquiry" (p. 42). Part of the confusion in defining inquiry in science education lies in the fact that it often simultaneously refers to the learning of both scientific concepts and the skills scientists use to solve problems of the natural world. The National Research Council's (1996) definition will serve as the basis for this article as it is relatively inclusive in terms of these two realms of inquiry, depicting it as,

> … a multifaceted activity that involves making observations; posing questions; examining books, and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. (p. 23)

Goals

Not only can the definition of inquiry vary, but so can its espoused goals (Anderson 2002). These goals emerge from educators' overall perspective of what it means to be scientifically literate, which necessarily shape students' experiences with inquiry. For many, the purpose of inquiry is to provide students with an authentic experience in science (e.g., Huberman & Middlebrooks 2000; Krajcik et al. 1998; Roth 1995; Schwartz et al. 2004) that entails a dual goal of learning both scientific concepts and the processes of science inquiry, as noted above. Others, in contrast, emphasize the role of inquiry in encouraging students to develop and use their creativity and imagination (e.g., Adams & Hamm 1998). Another goal arises from the social interaction of cooperative learning, which is inherent to an inquiry approach (Adams & Hamm 1998; Fox, Grosso, & Tashlik 2004) and which Roth (1995) views as a way to excite students about learning. Others consider this interaction to be a way to develop students' ability to successfully communicate with each other (Julyan & Duckworth 2000). Finally, some feel that an inquiry approach allows educators to be more aware of the cognitive processes occurring within the classroom (McLaughlin & Talbert 1993), and provides students opportunities to ask thought-provoking questions not normally posed in a general science classroom (Rop 2003; Scott 1994).

Students

Inquiry learning is a process students actively engage in within the science classroom (e.g., Anderson 2002; NRC 1996): It is "something that students do, not something that is done to them" (NRC 1996, p. 2). In traditional science activities, or "cookbook" laboratory settings, students are told either by the teacher or the textbook how to proceed (Llewellyn 2002). Skills are learned and practiced in isolation as students move from one technique to the next, each having little relationship to the other. In an inquiry approach, on the other hand, the skills become part of the overall process of solving a specific problem generated by the students themselves.

With an inquiry approach, students are expected to develop the mindset found within the scientific community (AAAS 1993; Aikenhead 1996; NRC 1996). These "habits of mind," as described by AAAS (1993), become the hallmark of what it means to be a good student as well as a good scientist. As Etheredge and Rudnitsky (2003) write:

> The notion that students should learn science by behaving like scientists has always had great appeal to educators. The notion that children, especially young children, *are* [author's italics] scientists, engaged in building theories about the world, adds to the cachet of inquiry. (p. 6)

Thus, students are expected to assume the role of "little scientist" as they develop their curiosity and inventiveness in posing questions and seeking answers about the natural world. The latter involves peer interaction (Adams & Hamm 1998) as students work cooperatively in groups, forming hypotheses, designing experiments, observing and analyzing results, classifying, drawing conclusions, and communicating all of the above, as well as critiquing each other's work (Crawford 2000; Fox et al. 2004). As the students acquire the skills and concepts of the scientific world, they also become more autonomous learners in both thought and action (e.g., Fradd et al. 2001; Lewellyn 2002). The active

student engagement in inquiry-based science education described above has a corresponding relationship to teachers' roles, which will be addressed next.

Teachers

Inquiry-based learning demands that science educators assume roles different from those in more traditional classrooms (Crawford 2000; Fox et al. 2004; Krajcik, Blumenfeld, Marx, & Soloway 1994; Ladewski, Krajcik, & Harvey 1994; Llewellyn 2002; Scott 1994). Teachers no longer function as the all-knowing authorities, imparting knowledge to the unknowing (Crawford 2000); rather, teachers and students are viewed as interactants in posing questions and seeking answers. The teacher thereby assumes the role of facilitator (e.g., Crawford 2000; Fox et al. 2004; Llewellyn 2002), observing and guiding students as the latter engage in processes of knowledge discovery. This thus engenders a shift from a traditional, predominantly teacher-centered classroom to a more student-centered classroom, where learners take an active role in their own education. Educators who make this shift no longer spend most of their time in front of the classroom lecturing to students, expecting them to "absorb" the proffered information. Instead, teachers circulate among the students, listening to them and guiding them with carefully crafted questions, modeling the behavior of scientists as the students are encouraged to engage in authentic scientific research (Crawford 2000). The teachers' role of "questioner" is repeatedly noted in the literature as a critical one (e.g., Hughes & Lee 2006; Krajcik et al. 1998). Teachers must become adept at the management of questioning and thinking skills as well as providing a physical classroom setting conducive to experimenting and working in groups. As Llewellyn (2002) notes, "as student involvement increases so does the need for the teacher to manage classroom movement and communication" (p. 8).

In sum, an inquiry approach to science education, which is based on constructivist ideology, can be characterized as inductive learning via problem-solving that involves active student engagement, both in posing questions and answering them. Creativity and critical evaluation skills are necessary for this as are communicative skills for interacting collaboratively with peers and with the teacher. This identification of the basic elements of an inquiry approach forms the backdrop for the next section, which provides a brief review of literature addressing inquiry-based science education.

Literature Review

As noted above, standards surrounding science education have increasingly revolved around incorporating inquiry into the classroom. This has resulted in an attendant increase in studies of this teaching approach. Many such studies have investigated its effectiveness, often yielding conflicting results. While reasoning and learning abilities were found to improve with inquiry teaching among 5th- and 6th-graders (Schauble, Klopfer, & Raghavan 1991), difficulties in procedural and interactional aspects of group interaction (Palinscar, Anderson, & David 1993) and lack of higher-level questions and peer feedback (Scardamalia & Bereiter 1992) were reported as well. Germann and Aram (1996) also found that most of the middle-school students in their study were unable to sufficiently relate their evidence to their hypotheses. In another study with middle-school classes using an inquiry approach, Krajcik, Blumenfeld, Marx, Bass, and Fredricks (1998) observed that students had difficulty generating testable questions, creating experimental designs that could answer their questions, and connecting their experimental results to scientific concepts. Haigh, France, and Forret (2005) were concerned with the relationship between "doing science" and genuine scientific inquiry, and concluded that student engagement in the science classroom only provided a "glimpse" thereof. Thus, despite Anderson's (2002) claim that research has generally shown inquiry teaching to produce positive results, challenges that demand attention still appear to exist, especially for non-mainstream students. A specific non-mainstream group that has received attention is students considered to be "at risk" (Hughes & Lee 2006; Mastropieri, Scruggs, Boon, & Carter 2001; Yerrick 2000). In the case of the lower track students in Yerrick's (2000) study, open inquiry was found to improve their learning. However, Moje, Collazo, Carrillo, and Marx (2001) found that the discourse of an inquiry approach posed a challenge for non-mainstream students. Language, literacy and culture have also been investigated in regard to bilinguals and English language learners (e.g., Fradd & Lee 2001; Fradd et al. 2001; Hampton & Rodriguez 2001; Lee & Fradd 1996; Lee & Fradd 1998; Lee & Fradd 2001; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes,2001). Rodriguez (1997) criticized the NRC 1996 standards for failing to adequately address ethnic issues. Lee (2003), in advocating attention to such issues, focused on studies of Hispanic and Haitian cultures, and

encouraged a research agenda that attends to Lee and Fradd's (1996, 1998, 2001) notion of "instructional congruency," which refers to "the process of mediating academic disciplines, such as science, with students' language and culture to make the academic content accessible and meaningful for all students" (p. 474). Although Hampton and Rodriguez (2001) found inquiry teaching to be effective in improving their bilingual students' thinking abilities and interpersonal skills, the students' limited English still posed a problem. Fradd et al. (2001) encouraged the development of materials for English language learners and proposed an inquiry matrix aimed at increasing their involvement as well as providing a transition to open inquiry. Lee (2003) furthermore called for teachers to be aware of the diversity among their students in attempt to avoid stereotyping and to better meet the pedagogical needs of their students.

Thus, while the literature has examined a limited number of specific groups in terms of diversity and the inquiry approach, and some authors have explicitly advocated increased attention to the congruency between students' language, culture, and science education, the use of cultural orientations as heuristics to gain a deeper understanding of the potential mismatch between students' culture and the "culture of inquiry" has remained largely underdeveloped. This following sections attempt to remedy this.

Cultural Aspects of Inquiry

Cultural orientations and dimensions, as identified in the literature, constitute patterns of values and beliefs that provide a lens through which inquiry-based science education can be viewed. When the values and beliefs embodied in an inquiry approach are not congruent with those of some students in the classroom, barriers can arise, necessitating a "border crossing," whereby students transition from their worldview to another in the quest for scientific understanding (Phelan, Davidson & Cao 1991). This transition can be smooth, managed, hazardous, and even impossible, according to Aikenhead and Jegede (1999). Which of these characterizes a student's experience will largely depend on how well the science educator is prepared to help the students cross the border. As Aikenhead (1996) says,

> Border crossing may be facilitated in classrooms by studying the subcultures of students' life-worlds and by contrasting them with a critical analysis of the subculture of science (its norms, values, beliefs, expectations, and conventional actions), consciously moving back and forth between life-worlds and the science worlds, switching language conventions explicitly, switching conceptualizations explicitly, switching values explicitly, switching epistemologies explicitly, but never requiring students to adopt a scientific way of knowing as their personal way. (p. 25)

This section will attempt to investigate potential cultural biases presented by an inquiry-based approach with the hope of contributing to a smoother border crossing and thus to greater learning. Hofstede's (1980, 1991) distinctions between collectivism and individualism, small and large power distance, and weak and strong uncertainty avoidance provide useful tools with which to discuss patterns of cultural orientation, as do Kluckhohn and Strodbeck's (1961) distinctions between cultures that emphasize doing as opposed to being, and those that view humankind as subject to nature, in harmony with it, or having mastery over it. Finally, Hall (1976, 1983) gives us the distinction between high-context and low-context communication and monochromic versus polychronic orientations toward time. Such cultural orientations provide useful heuristics with which to investigate the borders students may need to cross in order to gain entry into the world of inquiry.

It should be noted that *culture*, as used here, refers to the "deep culture" of underlying values and beliefs. This culture is neither deterministic, static, nor monolithic. Furthermore, generalizations regarding cultural orientations refer to a group and do not necessarily apply to all members of that group; not all Hispanics (a broad label in itself), for example, have the same cultural background. It is thus important to heed Holliday's (2003) warning to avoid "culturalism," that is, "essentialist, cultural overgeneralizations" (p. 113) that lead to stereotyping. This paper will therefore refrain from assigning cultural orientations to specifically named groups. What is important is not that teachers be armed with a "grocery list" to automatically label students of a certain ethnic background, for example, but rather that they develop an awareness and sensitivity to their own cultural values, those embodied by the inquiry approach and its implementation in their classrooms, as well as to the potential ways all of these may conflict with learners' cultural backgrounds. As Powell and Caseau (2004) assert, most American classrooms reflect

low-context and individualistic orientations while an increasing number of students come from high-context, collectivistic backgrounds.

Science

Science itself has arisen within the worldview of western culture (Ogunniyi 1988), which has transferred its rationalistic and individualistic values to a science that is deemed to have power to control the natural world. However, even within western cultures differences can exist which can color the ways an inquiry approach might be construed, enacted, and received.[2] For example, Europeans tend to approach science in a more deductive way than US Americans, placing greater importance on theorizing than on empirical observation and quantification, the latter being viewed by US Americans as contributing to objectivity (e.g., Stewart & Bennett 1991). Those whose backgrounds are rooted in non-western cultures may encounter significant difficulties in western approaches to science education, including the currently popular inquiry approach. The analytical style of western science, for instance, is foreign to many cultures that view scientific phenomena in a more holistic or relational way and that may have different assumptions about the nature of knowledge itself (e.g., Ogunniyi 1988). The western instrumental, mechanistic view of the natural world likewise stands in opposition to views which include the interaction of personal, social, and supernatural forces (Lee & Fradd, 1998).

Problem-Solving: Doing and Counterfactual Speculation

Kluckhohn and Strodtbeck (1961) characterize the U.S. as a "doing" culture. In confronting a problem this means taking action to find a solution. This is reflected in inquiry-based science education in the form of identifying a problem regarding natural phenomena, considering alternative ways to arrive at a solution, choosing one of the solutions, testing it, analyzing the results, and drawing conclusions. Beginning this endeavor involves counterfactual speculation of an objective if-then type (cf. Stewart & Bennett 1991). Such an approach may be foreign to members of cultures that resist counterfactual thinking or arrive at alternative solutions to problems via intuition (e.g., Stewart & Bennett 1991). Students new to the U.S. may never have been exposed to counterfactual speculation or to engaging in problem-solving that demands such learning by doing.

Discourse

As Richmond and Striley (1996) point out, science education entails both a conceptual and a social dimension. Discourse is central to both dimensions and can be viewed as playing a role in at least three ways, all of which can overlap with one another: discourse of the discipline itself, student-teacher interaction, and peer interaction. Indeed, Crawford, Kelly and Brown (2000) note that the role of discourse and language has received increased focus in studies of science education. The three aspects of discourse will be discussed below.

Discourse of the Discipline

As Brown (1990) points out, "scientific English is far from being value-free" but "derives from a particular philosophical view held in a particular culture" (p. 13). The author identifies assumptions and presuppositions, often unstated, that find reflection in the discourse of the discipline (e.g., the value placed on truth precludes adjusting any of the outcomes of a reported study; scientific reports are expected to include outcomes relevant to the hypothesis and exclude irrelevant ones). Hofstede (1986) ascribes an emphasis on impersonal "truth" to be associated with small power distance orientation as opposed to an emphasis on personal "wisdom" valued by large power distance societies. It is impersonal truth that is valued in the inquiry approach.

A general hallmark of western scientific language is precision and clarity; nothing is left to intuition. A learner from a low-context society, where the majority of information is explicitly contained in the message, will thus likely do better in meeting the expectations for group communication and reporting an experiment and its results than will a learner from a high-context society, which places the onus on the reader or listener to infer meaning from what is expressed (e.g., based on context and shared background experiences).

While teachers may perceive their directions to be clear and precise, however, they may not be perceived as such by all students. As Holliday (2003) states, "One of the problems with the activity-discovery approach – "look at the…and find out how to…" …is that what participants are supposed to do is not always transparent to people not brought up in this particular professional discourse" (p. 121). The types of questions posed in an inquiry approach will also be more open-ended rather than those that elicit mechanical responses. This may well pose a challenge for those students who have a high uncertainty avoidance orientation and consequently view a lack of predictability to be undesirable.

Student-Teacher Interaction

The interaction between students and teachers in an inquiry approach is somewhat different from that of more traditional, teacher-fronted science classrooms. The importance of the teacher assuming a non-authoritarian, facilitator role is repeatedly cited in the literature as a characteristic of the inquiry approach (see above). The teacher as a non-authority figure creates a classroom conducive to risk-taking and exploration, which are likewise characteristics of an inquiry approach. Those students more accustomed to the teacher dictating content, procedures and answers to questions may perceive there to be a lack of structure, which leads to feelings of insecurity.

In general, an inquiry approach tends to contain a considerable amount of ambiguity and encourages a great deal of self-directed learning. As pointed out above, learner autonomy is part of the philosophical underpinnings of the inquiry approach. The teacher's role in an inquiry approach is thus more compatible with those who come from small power distance and weak uncertainty avoidance cultures as opposed to large power distance and strong uncertainty avoidance cultures. Characteristic of small power distance is a student-centered classroom that places a high value on student initiative (Hofstede 1986). Weak uncertainty avoidance is likewise compatible with students being rewarded for innovative approaches to problem-solving as opposed to being rewarded for accuracy (Hofstede 1986). The importance placed on students' ideas and thought processes and their exploration also relates to espoused values of equality associated with a small power distance orientation, which imbue learners with rights relatively equal to those of the teacher. Additionally, students with a high power distance orientation may refrain from asking the teacher questions unless it is done privately, perhaps after class, if such an opportunity exists, in order to avoid threatening the teacher's face in front of the entire class (cf. Koyama 1992)

Peer Interaction

Because an inquiry approach involves peer interaction in cooperative groups, social and discoursal aspects are especially pertinent. Group members bring with them expectations about the purpose of cooperative groups and how to relate to others in such a context, including expectations regarding leadership styles (cf. Hughes & Less 2006; Richmond & Striley 1996). Some students may not view peer-interaction or group work as a form of viable learning at all, but as a game. The overall desirability of group work can also vary significantly across cultures (McCargar 1993). Jacobs and Ratmanida (1996) suggest that group work is compatible with those whose orientations tend to collectivism, weak uncertainty avoidance, and small power distance.

One aspect of group work is its task of posing a problem and solving it, which, in the West, would be expected to lead to the expression of differing views as members seek to reach a consensus in order to proceed. This in turn may result in conflict. Different views of conflict (e.g., productive vs. nonproductive) and related approaches to conflict management as found in different cultures will thus also impact group work. Cultures that emphasize harmony and maintaining another's face within communicative exchanges will have a different style in dealing with conflict than will those who emphasize independent, critical thinking. Ting-Toomey (2000) notes that differences between high-context and low-context orientations can differentially impact responses to conflict. Because high-context cultures (which also tend to be collectivistic) are more reticent about openly expressing ideas, those with such an orientation may tend to perceive expression of conflicting ideas as an impediment to making progress (e.g., reaching a consensus). For such students, conflicting views would likely be handled with less directness than they would be by someone from a low-context culture (which typically is also an individualistic culture). Furthermore, students' presentation of their experiment to their peers requires discussion and perhaps critique. This can appear to be inappropriate to some as well as difficult if "polite" questioning and disagreement skills have not been developed. Cultures also differ in their readiness to

compromise (Stewart & Bennett 1991) and their expectations regarding the extent to which a teacher should mediate in conflict situations. Furthermore, for some, establishing a cohesiveness and belongingness within a group is an essential prerequisite to any exchange of ideas. This is especially true for collectivistic cultures that make significant distinctions between in-group and out-group. Effective communication in peer interaction also involves shared norms regarding turn-taking, that is, shared perceptions of the appropriate amount of overlap in verbal contributions. Sequential turn-taking tends to be consistent with the linear monochronic view of time associated with individualism. Those with a polychronic orientation may well tolerate more overlap in turns and thus be perceived as rude and pushy by those with a more monochronic orientation. Miscommunication can easily arise in peer interaction when discourse norms are not shared. This can result in negative personal attributions as well as in some voices not being heard at all.

Time

Pace is also a major consideration in the inquiry approach (Hughes & Lee 2006). Inquiry-based learning may tend to be more non-linear than more traditional approaches in terms of its process-orientation, which also means a de-emphasis of arriving at one correct answer. Additionally, those who value efficiency and view its attainment to lie in quick decision-making may find themselves at odds with those whose view of decision-making involves long discussion that considers all aspects of an issue, including a review of its history. Trial-and-error solutions preferred by the dominant U.S. society may be resisted by those who view a thorough understanding of a problem as a prerequisite to attempts at solving it (Stewart & Bennett 1991).

Once a plan of attack has been agreed upon in the inquiry approach, its execution (e.g., the testing of a hypothesis) is expected to proceed without interruption as observations are systematically recorded. This is congruent with the expectations of members of a monochronic society, but may well be opposed to those with a more polychronic orientation, who may build more flexibility into their plans in order to allow for potential relational issues (cf. Ebsworth & Ebsworth 1997). The structure of strict timetables is also likely to be preferred by those with strong uncertainty avoidance (cf. Hofstede 1986). An awareness of the above, can enhance the choice of how an inquiry-based approach is designed, implemented, and modified. One shoe does not fit all.

Possible Construals and Adaptations

If inquiry-based science education is to be successful it must accommodate the needs of the student population, considering its members' backgrounds and expectations. Ways must be found to cross the borders between the assumptions and expectations a student brings to the classroom and those of an inquiry approach. This may entail different ways of doing inquiry to increase its cultural compatibility with the students' cultures. Indeed, it has been recognized that inquiry can be conducted in various ways (e.g., Abd-El-Khalick et al. 2004: Anderson 2002), including differing degrees of structure (Colburn 2000; Fradd et al. 1998) as well as varied teacher involvement and explicitness of instruction. The challenge is how to provide sufficient information and structure with which to efficiently pose questions, develop hypotheses and ways to test them, and how to base this on learners' experience and background knowledge with an increasingly diverse learner population.

If the inquiry approach values that which students bring with them, then, following Banks and Banks (1993), it is important to learn about one's students' beliefs and attitudes; to this end, the authors suggest asking students to complete the following open-ended sentence: "When I think about science, I…" (p. 143). Given the increased understanding the completions may yield, the teacher should take at least two further preliminary steps to help students to transition to inquiry as a new approach (cf. Krajcik et al. 1998). The first step involves a clear articulation of its assumptions, goals, and central elements, and how they might impact those with contrasting worldviews. The second step should include activities to promote the development of communication skills for effective collaboration in groups, and for the articulation of results, explanations and conclusions. Such activities might include preliminary role-plays focusing on the practice of listening skills, and useful questioning and disagreement phrases as well as on formulaic phrases for reporting results. Once such preliminary steps are taken, further attention should be given to establishing specific objectives and providing clear instructions and examples, both verbally and in writing, thereby reducing ambiguity and uncertainty.

Before asking groups to work together, time should be provided for activities that allow students to get to know each other. Ice-breaker activities could be used for this, with topics focusing on natural phenomena in the students' environment. Such activities should attempt to highlight students' commonalities and differences, and the value of both. It may also be beneficial to keep the same groups throughout a semester (Hoffman 2000) in order to establish strong personal connections and subsequent strong in-group feelings. Jacobs and Ratmanida (1996) found it helpful for large power distance oriented learners if teachers made a point of giving overt approval to a group's decisions. Also, if teachers are attentive as they circulate among the students, giving encouragement and varying support according to student need, uncertainty can, in general, be lessened.

The belief in learner autonomy, which is part of an inquiry approach, calls upon teachers to be sensitive to the discomfort this might present for some students. Holliday (2003) cites Breen and Mann, who contend that "students need to be enabled in appropriate ways to exercise and develop an autonomy which they already possess, rather than being 'trained' into a new way of learning" (p. 18). Therefore, teachers need to develop students' autonomy both systematically and carefully (cf. Diaz-Rico & Weed 2006), providing more initial structure and support (cf. Scardamalia & Bereiter 1992) and only gradually withdrawing it. A framework for this is provided by Colburn (2004), who describes varying degrees of structure within an inquiry approach, ranging from structured inquiry to guided inquiry to open inquiry.

Also, by allowing learners to present experiment results in different ways (e.g., graphs, narratives, pictures, posters, booklets), differing preferences and strengths can be catered to. For those uncomfortable with sharing ideas orally within a group, written expression may be an alternative, at least initially. This might conceivably also include e-mail or websites set up for this purpose.

Teacher Education

Colburn (2000) places a great deal of responsibility for the success of inquiry-based science education on the teacher. Indeed, teachers can be viewed as the gatekeepers and providers of pathways to knowledge and skills; they are the central decision-makers in regard to the way in which an inquiry approach is construed and adapted in response to student needs. As noted above, utilizing a student's prior knowledge and experience is a keystone of learning within an inquiry approach. When this prior knowledge and experience is incompatible with the principles of the inquiry approach, the challenge of successfully implementing the approach is greater, demanding an increased awareness of and sensitivity to such incompatibility on the part of the teacher. It is thus important to consider who the teacher is, that is, her or his beliefs, values, prior experiences, and discourse. Educators must reflect on their own classroom practices as well as on their overall beliefs about teaching, learning, and the nature of science (e.g., Ladewski, Krajcik, & Harvey 1994; Powell & Caseau 2004), recognizing that these may be different from many of their students' (Hofstede 1986). This recognition can lead to a greater awareness of the effect these differences might have on the learning that takes place with an inquiry approach.

Anderson (2002) suggests that culture may be the most important of three dimensions that present a dilemma for teachers implementing new approaches. Indeed, the author surmises that it may be the most important dimension. Addressing this cultural dimension in an inquiry approach, however, does not involve a set recipe. What is needed is a basis for informed pedagogical decision-making in the varied contexts with the varied student populations that teachers will encounter. To this end, teachers need to be aware of the varied expectations that a diverse class can represent in order to implement inquiry in a way that will not place hurdles in the way of learning but rather lower and remove them. This points to relevant pre-and in-service teacher education, where the focus is placed on the development of insights into varied cultural orientations, their potential effect on learning expectations and preferences, and strategies and skills for dealing with diverse learner populations (cf. Barba 1993). In short, teachers must develop intercultural competence.

Conclusion

Because the inquiry approach enjoys a great deal of current popularity in the science education community (Colburn 2000), it has become a major pathway to access scientific knowledge and gain membership in the scientific community. Clearly, diverse student populations present challenges to effective inquiry-based science education in terms of cultural background experiences and expectations regarding the nature of science itself, its discourse, pace, autonomy in learning, and the role of teachers

and students. An awareness of these challenges and their bases is necessary to help students cross borders and do so with a minimum of bumps as science is made accessible to all students. It is hoped that the discussion in this paper will contribute to future research and classroom practice that will further this endeavor.

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Endnotes

[1] While it is recognized that inquiry-based science education may not be embraced by all, its current popularity requires attention to its effective implementation. It is thus beyond the scope of this paper to argue for or against the theoretical and empirical basis of the inquiry approach itself.

[2] Cohen (1969) also interestingly noted that American children from low-income families exhibited a more non-western cognitive style.

About the Authors

Dashia Magee is an assistant professor in the Educational Administration and Secondary Education at the College of New Jersey. She has published in areas of teacher education and science education. She has taught course in science education, curriculum studies, and social foundations.

A.J. Meier is a professor in the MA TESOL/Applied Linguistics Program at the University of Northern Iowa. She has published in the areas of politeness theory, cross-cultural apologies, language and gender, intercultural pragmatics, and language teacher education. She has taught theoretical and applied linguistics and presented intercultural communication workshops in the United States, Russia, and Austria.

Authors' Addresses

Dashia Magee
The College of New Jersey
Forcina Hall 382
P.O. Box 7718, 2000 Pennington Rd.
Ewing, NJ 08628
P) 609.771.2395
F) 609.637.5197
e-mail: dmagee@tcnj.edu

A.J. Meier
University of Northern Iowa
e-mail: aj.meier@uni.edu