Relationships among informal learning environments, teaching procedures and scientific reasoning ability

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To cite this article: Brian L. Gerber, Anne M.L. Cavallo & Edmund A. Marek (2001) Relationships among informal learning environments, teaching procedures and scientific reasoning ability, International Journal of Science Education, 23:5, 535-549

To link to this article: http://dx.doi.org/10.1080/09500690116971

Published online: 26 Nov 2010.
Informal learning experiences have risen to the forefront of science education as being beneficial to students' learning. However, it is not clear in what ways such experiences may be beneficial to students; nor how informal learning experiences may interface with classroom science instruction. This study aims to acquire a better understanding of these issues by investigating one aspect of science learning, scientific reasoning ability, with respect to the students' informal learning experiences and classroom science instruction. Specifically, the purpose of this study was to investigate possible differences in students' scientific reasoning abilities relative to their informal learning environments (impoverished, enriched), classroom teaching experiences (non-inquiry, inquiry) and the interaction of these variables. The results of two-way ANOVAs indicated that informal learning environments and classroom science teaching procedures showed significant main effects on students' scientific reasoning abilities. Students with enriched informal learning environments had significantly higher scientific reasoning abilities compared to those with impoverished informal learning environments. Likewise, students in inquiry-based science classrooms showed higher scientific reasoning abilities compared to those in non-inquiry science classrooms. There were no significant interaction effects. These results indicate the need for increased emphases on both informal learning opportunities and inquiry-based instruction in science.

Introduction

A major goal of science education is to improve science literacy among students. However, what are the means by which this goal may be accomplished? What skills and learning should students acquire to promote this goal? Much of science education’s attention is focused on formal learning environments; that is, the structured classroom setting. In these settings, education takes place in an organized manner such that the learner and the teacher are placed together with the prescribed intent of promoting learning. The instructional procedures in formal settings vary from teacher-centred, with didactic transmission of knowledge, to highly student-centred, experiential, where knowledge is socially constructed. With emphasis on fulfilling the curricular goals, the formal setting tends to implement a set agenda with little, if any, importance ascribed to
childrens’ prior knowledge, memories, and experiences outside the classroom (Osborne and Wittrock 1983). Yet, it helps students to use everyday, out-of-school experiences as they engage in discovery of scientific phenomena, use their inquiry skills, and engage in active discourse with the teacher and peers. Such inquiry teaching supports the goals of national initiatives (AAAS 1990, NRC 1996) to promote the development of science reasoning and ultimately, science literacy among students.

However, the formal classroom is not the only setting where such goals may be accomplished. The majority of students’ science learning experiences actually take place outside of formal classroom settings and in informal learning environments. Such learning may take place at home, in museums, through club membership activities or in simple everyday experiences. Nonetheless, little is currently known about the impact of students’ experiences in informal learning environments on science learning and/or skill development.

Further, what links do students make between knowledge acquired in the classroom and experiences outside the classroom? How might experience outside of the classroom interface with formal classroom instruction to bring about learning? Consider the following anecdotal data obtained through pilot investigations of this research. A group of students was given a paper-pencil test on the Piagetian conservation of volume task (Lawson 1995a). In this task, students were to observe drawings of two graduated cylinders with the same water levels. The students were to determine the resulting water levels after hypothetically dropping equal-sized steel and glass balls into one of each cylinder. One seventh-grade student explained (correctly):

Because I’ve learned that if I put my hand in a glass of water, then my bigger-handed cousin puts his hand in a glass of water and we take them out, his glass has less water and mine has more because his hand is bigger.

So, if the balls were the same size then the water level would have to be the same.

In this response, the student used an example from real-world experiences to demonstrate an understanding of conservation of displaced volume. This student’s response raises important questions regarding relationships among the activities which may occupy a student’s time in informal learning environments, the nature of their in-school science experiences and scientific reasoning abilities. Each of these domains (informal learning, formal learning and reasoning ability) is examined in more detail, including how they may interconnect to foster student learning.

Informal learning

Most children attend school seven hours a day, five days a week for thirty-six weeks of the year. From the time a student begins schooling and finishes high school, each has spent approximately 11,000 hours in the classroom and 65,000 hours, sleep excluded, outside the classroom (Medrich et al. 1982). The types and frequencies of activities in which children are engaged during this time may have profound effects on their abilities in school and functioning in society. Experiences that may occupy childrens’ time may be as varied as the children themselves. Watching television, playing electronic games, reading, performing family chores
and participating in sports are but a few of the myriad of informal activities which may comprise childrens' experiential time outside formal educational settings.

The importance of what is learned informally has long been reported, but only through anecdotal statements. Hall (1907) stated that the importance of summer vacations for boys in the New England States, ‘…appears to me to have constituted about the best educational environment for boys at a certain stage of development ever realized in history, combining physical, industrial, technical with civil and religious elements in wise proportions and pedagogic objectivity’. Bruner (1961) more directly stated, ‘It also goes without saying that there are certain forms of child rearing, certain home atmospheres that lead some children to be their own discoverers more than others’.

Interest in informal learning research, and acknowledgement of its importance to formal education, has risen over the past 25 years (Lucas 1991), yet, little research is available concerning informal learning. Using the ERIC database as an indicator of interest, Lucas (1991) found 85, 99, and 163 informal science learning entries from the periods 1966-1976, 1977-1983, and 1983-1991, respectively. The articles were primarily commentaries on museum programmes or descriptive museum research. Only a few dealt with the process of learning outside the school environment. The authors of this manuscript continued the survey and found similar results from the 167 articles published from the period 1992-1999. Ramey-Gassett et al. (1994) and Dierking and Falk (1994) provide extensive reviews of all current and past research in this area.

Although science museums are one type of informal educational setting recognized as an important asset to science learning, the majority of childrens’ non-school time is spent on informal activities unrelated to museum activities. This time is unaccounted for in science education research due to the difficulty of evaluating such heterogeneous subjects, learning environments, activities and everyday learning situations. Aside from museum studies, research on informal learning is not as researcher friendly as the traditional classroom arena. The research which is available indicates that informal science learning contains the same fundamental elements that may be present in effective formal learning situations (e.g. cognitive challenges and social interaction) (Wright 1980, Lucas 1983, Bierbaum 1988, Edeiken 1992, Chinn and Brewer 1993). Therefore, informal science learning may facilitate the development of reasoning abilities that are pre-requisites to learning and understanding science processes and concepts.

**Scientific reasoning ability**

Scientific reasoning ability involves a range of thinking patterns between empirical-inductive thought to hypothetical-deductive thought (Lawson 1995a). Empirical-inductive thought is characterized by the ability to accurately order and describe perceivable objects while hypothetical-deductive thought allows students to create and test explanations for non-observable (hypotheitical) phenomena (Lawson 1995a); skills clearly relevant to learning in scientific disciplines.

According to Piaget (1964), direct experience (physical and logical-mathematical), cognitive conflict and social interaction are important factors that help learners construct their own knowledge through formal learning experiences and informal learning experiences. Vygotsky (1978, 1986) and Rogoff (1990) further emphasize that social interaction and discourse are highly important to students’
construction of knowledge. The three factors together promote the development of a cognitive framework or schemata (Piaget 1964, Hendry and King 1994). The complexity of the schematic framework reflects a measure of a child’s scientific reasoning ability (Aday and Shayer 1990). Thus, experiences that may produce cognitive conflict and social discourse help develop children’s reasoning abilities. Such experiences may befall children through their teachers’ use of certain classroom teaching procedures, and their own enriched informal learning experiences.

Inquiry teaching procedures

Inquiry-oriented teaching approaches focus on providing students direct experiences with phenomena that induce cognitive conflict and hence encourage learners to develop new knowledge schemes that are better adapted to experience. Practical activities and active discourse form the core of such pedagogical practices. In classes taught by inquiry, individuals are actively engaged with others in attempting to understand and interpret phenomena for themselves; and social interaction in groups provides a stimulus of differing perspectives for reflection. The teacher’s role is to provide the physical experiences and to encourage such reflection.

One model of inquiry is the learning cycle (Lawson et al. 1989, Renner and Marek 1990, Lawson 1995a, 1995b, Marek and Cavallo 1995, 1997). The learning cycle consists of three phases: exploration, term introduction and concept application (Marek and Cavallo 1997). In the exploration, students engage in laboratory experiments and collect data on observed science phenomena. The exploration engages students in some level of disequilibrium or cognitive conflict as they struggle to make sense of their observations and experiences. In term introduction, the teacher guides students toward compilation and representation of their collected data. Through use of the data and classroom discourse, students prepare a statement that represents their understanding of the science concept. After students have attained concept understanding, the teacher may provide related scientific terminology or ‘labels.’ In the third phase, concept application, students expand their understandings by using the concept in different contexts. Teachers often facilitate concept application through computer programmes, videos, readings, laboratory investigations, demonstrations, field trips or discussion. Through application activities, students organize the concept in relation to what they already know, and relate the concept to real world experiences. Importantly, throughout the learning cycle, students work in collaborative groups; represent data and show interpretations in multiple forms (graphs, tables, written oral description), and; engage in active discourse with peers and the teacher. The teacher facilitates the students’ learning process, asking probing questions without revealing the concept or related terminology until students have constructed and stated their understandings. Other inquiry-teaching models exist with each usually focusing on one primary instructional method, such as Socratic questioning or discrepant events. However, all other inquiry models have common elements to the learning cycle and may actually be contained within it.

Inquiry classroom environments, such as those using the learning cycle, appear consistent with how children learn naturally in informal learning environments; in essence, the development of reasoning abilities is promoted through students’ experiences, cognitive conflicts and social interactions. In inquiry classrooms, teachers help the children engage in many of the same mental activities
that occur in informal learning environments. However, in informal learning environments the teacher’s role may be substituted by the interactions among more knowledgeable peers, siblings, or adults in each shared experience.

**Learning environments and reasoning ability**

It is well documented that inquiry teaching promotes scientific reasoning abilities (Adey and Shayer 1990, Lawson 1995a, Marek and Cavallo 1997). Adey and Shayer (1990) demonstrated that acceleration of cognitive development (reasoning ability) was possible among middle and high school students through long-term, inquiry-oriented interventions. The authors stated that the important difference between the expert and the novice is the experiential knowledge base of the former. This experiential knowledge base results in higher order schemata formation in the expert. It is this higher order schemata that allows the expert to achieve understanding with less learning, compared to the novice. In addition to inquiry-based formal learning environments, students’ experiential knowledge base may be established in enriched informal learning environments.

What is often overlooked is that science learning has begun long before children enter formal science learning situations. The extent to which formal science learning can take place is, in large part, dependent upon the cognitive framework constructed through informal experiences. In this research, it is proposed that students who participate in few informal learning opportunities or have relatively ‘impoverished informal learning environments’, may have less well-developed schemata with which to relate formal science experiences compared to those with many informal learning environments or ‘enriched informal learning environments’. Research from Adey and Shayer (1990) suggests that the less-developed schemata of students with impoverished learning environments would produce less formal science learning compared to students with well-developed schemata as a result of enriched informal learning environments.

A study by Zuzovsky and Tamir (1989) also highlighted the potential of informal learning. The research examined relationships between school variables (e.g. school conditions, principals, teachers) and home variables (e.g. parents’ years of formal education, number of siblings in family, books at home) in the science achievement of 2,599 elementary school students. The data were collected through mailings of a battery of tests and questionnaires to 86 randomly selected schools in Israel. The authors found that school variables contributed greatest to achievement in biology and physics. School variables contributed the least to student inquiry skills. The authors attribute this finding to the idea that inquiry skills may be more dependent on general intellectual abilities rather than on a quality facilitated through formal schooling efforts. Compared to school variables, the contribution of home variables to achievement of subjects not taught in schools was about four times greater. The authors concluded that science knowledge was strongly dependent on school learning when achievement is measured on knowledge of facts and mastery of specific concepts. A much larger contribution of school variables was found for the explanation of variance in achievement among students of low socio-economic status (SES) (Zuzovsky and Tamir 1989). Compared to students of high SES, those students of low SES most likely have impoverished informal learning environments. After controlling for student ability in low SES schools however, they found the school contribution to achieve-
ment decreased significantly, with home factors now explaining most of the variance. Since students with impoverished informal learning environments (low SES) come to school with less-developed schemata compared to students with enriched informal learning environments (high SES), formal science learning played a greater role in science achievement than informal science learning. Similarly, students with well-developed schemata learned much of their science through informal experiences and for them the contribution of home variables to science achievement was much greater than the contribution of school variables.

A similar study by Tamir (1990) attempted to identify factors associated with informal science learning. Tamir surveyed 544 tenth-grade students from six different schools in Israel. A questionnaire required students to respond with information regarding their personal lives (e.g. home background, interests, hobbies, aspirations, achievement in math and science), out-of-school activities related to school learning (e.g. after school discussions, reading, watching television), and attitudes toward science learning and scientific literacy. Analyses of the results indicated positive correlations of television watching, after school discussions, listening to the radio, reading, and museum visits to attitudes toward science, perceptions of the relationship between school science and everyday life, school environment, parents’ occupation, career aspirations, and intentions for further study. The author found that participation in out-of-school informal science activities was strongly associated with a commitment to science and science learning.

The primary aim of these previous studies was to examine specific factors (e.g. parents’ education, number of books at home) and science-related activities (e.g. after school academic discussions, museum visits) that were easily recognized as educational. Previous research has not quantified informal learning environments by examining the wider spectrum of activities in which students might be engaged. Activities not considered science learning opportunities (e.g. participating in sports, cleaning the home, shopping for groceries) are all part of informal learning environments and may provide the experiences, cognitive conflict and social interaction required to facilitate the development of scientific reasoning abilities. Furthermore, research has not yet explored how formal classroom learning experiences may interface with informal learning experiences as they may be related to students’ development of science reasoning ability. Thus, the purpose of this study was to explore possible differences in scientific reasoning abilities in relation to students’ informal learning environments (impoverished or enriched), science classroom teaching procedures (non-inquiry and inquiry) and the interaction of these variables.

Methodology

Sample

The sample consisted of 1,178 students enrolled in seventh-, eighth-, ninth-, and tenth-grade science classes. Students were enrolled in eight middle schools and two high schools from a midwestern state. Schools were located in rural, suburban and urban settings and ranged in size from approximately 50 students per grade level to approximately 325 students per grade level. Students of nine female teachers and seven male teachers participated in the study. Science teaching
experience among these sixteen teachers ranged from 2-26 years and averaged 11.4 years.

Students absent from any of the assessments or tests were eliminated from the original sample. In addition, only those students with impoverished informal learning environments and those students with enriched informal learning environments were selected to participate in the study. Thus, approximately 50% (those with mid-range learning environments) were removed from the original sample of students. The final sample consisted of 505 students. Teacher interviews and questionnaire data revealed those students in the final sample represented relatively equivalent SES and academic abilities. The sample consisted of an approximately equal ratio of males to females and an ethnic distribution representative of the larger population of the state. A description of the final sample is provided in table 1.

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<td>10</td>
<td>8</td>
<td>169</td>
<td>3</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
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<td>258</td>
<td>22</td>
<td>18</td>
<td>406</td>
<td>10</td>
<td>28</td>
<td>21</td>
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</table>


Instrumentation and procedures

Informal Learning Opportunities Assay. The Informal Learning Opportunities Assay (ILOA) is a 41-item questionnaire designed to measure, qualitatively and quantitatively, students’ informal learning environments (Gerber 1996). After initial development of the instrument, an expert panel consisting of two science education professors, an educational psychology professor and two middle school science teachers reviewed the ILOA. The instrument was also pilot tested using 49 students. Six students from this pilot study were interviewed regarding their interpretation and understanding of items. Suggested modifications obtained from the reviews, pilot test and interviews were used to produce the final form of the instrument. The coefficient of stability was measured with a test-retest technique using Pearson correlation. A reliability coefficient of 0.86 was found using a representative sample of 115 ninth-grade students over a 75-day period.

The ILOA was designed to be completed by middle school and high school students without requiring an interview format. The instrument required students to respond to items primarily concerning social activities with family and/or friends; activities done alone; school-related activities; lessons, classes or group activities not school-related; work and domestic chores; and travel. Sample questions from the ILOA include:
4. Do you have any hobbies, like collecting or making things? yes no
   * If yes, what are your hobbies?
   1. ________________________  2. ________________________

16. How often do you usually go to a library?
   once a week or more a few times a month a few times a year or less

27. Have you ever done volunteer work for any group? yes no

41. Have you ever traveled outside the state? yes no
   * If yes, list in the space below where you traveled and when you traveled there.

The instrument included both quantitative and qualitative responses. The quanti-
titative responses were scored such that most responses received either one point
or a zero. The qualitative responses were used to support and verify quantitative
data. The scoring system that was established was reviewed and evaluated as sound
by the panel of experts. A high score on the ILOA represented an enriched infor-
mal learning environment and a low score represented an impoverished informal
learning environment. (See Gerber et al., accepted for publication, for a complete
description of the instrument and scoring techniques used in this research.)

Classroom Test of Scientific Reasoning. The Classroom Test of Scientific
Reasoning (CTSR) developed by Lawson (1995a), was used to determine students’
scientific reasoning abilities. The CTSR is a 12-item written test designed to assess
students’ ability to conserve weight and volume; separate variables; and use pro-
positional logic, combinatorial reasoning, and correlations. Each item is worth
one point and requires students to respond to a question as well as explain the
derivation of their answer. The student must correctly answer the question and
provide a reasonable explanation for their answer for the item to be considered
correct. A Cronbach alpha reliability coefficient for the CTSR was \( r = 0.75 \) as
determined in a study by Cavallo (1996) for a sample of 189 tenth-grade students.
The possible range of scores was 0 through 12 and these scores were used in the
analyses.

Inquiry and non-inquiry science teachers

Each teacher participating in this study was interviewed and subsequently identi-
fied as an inquiry science teacher or a non-inquiry science teacher. The inquiry
model selected for this research was the learning cycle. Thus, two criteria were
used to identify teachers who use inquiry as their primary teaching method. First,
within the past 10 years these teachers successfully participated in at least one
inquiry-oriented science teaching methods course emphasizing the learning cycle
teaching procedure and theory base; or participated in at least one learning cycle
inservice programme for science teachers. Second, all teachers were asked to pro-
vide a description of the classroom activities taking place two weeks prior to the
interview and two weeks following the interview. Inquiry teachers described
materials-rich, student-discovery activities as having a central role in their class-
rooms. Furthermore, the teachers relied heavily on questioning and did not reveal
concepts to students prior to their explorations. Teachers consistently allowed
students to formulate explanations of phenomena for themselves. The students
frequently worked in groups and discussed their data and conclusions, and often
presented findings and explanations to the class in both written and oral forms.
Teachers identified as non-inquiry science teachers did not participate in an inquiry-oriented (learning cycle) science methods class or attend an inquiry-oriented inservice programme at any time during their career. Also, descriptions of their four weeks of science classes did not involve any activities that could be characterized as inquiry. The activities most frequently discussed by this group of teachers included, giving lectures, doing book reports, completing worksheets, watching videos, doing verification laboratories, and playing computer games. The teachers regularly provided explanations of science phenomena to students in place of and/or prior to any explorations (verification). The students most often worked alone and typically did not discuss or share their ideas with classmates or the teacher.

Teachers identified as inquiry science teachers for this study averaged 11.6 years of science teaching experience and included four females and two males. Teachers identified as non-inquiry averaged 10.1 years of science teaching experience and included five females and five males.

**Research design**

The ILOA was administered by the researcher, or by the classroom teacher in the presence of the researcher, early in the fall semester to assess students’ informal learning environments. A preliminary study showed no difference in ILOA scores for students in different grade levels. The ILOA was given earlier in the school year to facilitate scoring and determine informal learning environment groups. Results on the ILOA from this initial group of 1,178 students formed a continuum of scores from very low (impoverished informal learning environments) to very high (enriched informal learning environments). From the initial set of students, two subsets were identified. One subset consisted of those students scoring in the lowest 25% on the ILOA (impoverished informal learning environment) while the other subset consisted of those students scoring in the highest 25% on the ILOA (enriched informal learning environments). This division ensured that the two subsets were different with respect to their informal learning environments. Students scoring in the 50% midrange on the instrument were not selected for participation in this study.

The researcher administered the CTSR in February to all students. This time of the year was chosen to allow students as much time as possible to experience the teaching procedure (non-inquiry or inquiry) used in their particular science classrooms.

The categorical variables from the ILOA (low, high), teaching procedure (non-inquiry, inquiry) and the interaction term (ILOA × teaching procedure) were independent variables and the CTSR score was the dependent variable in the data analyses. Analyses of these variables among grade levels followed a trend study research design as described by Borg and Gall (1989). This study used an alpha level of $UI < 0.05$ as the criterion for significant results.

**Results**

Of the 505 students in the final sample, those in the lowest 25% attained ILOA scores that ranged from 6-19 and those in the highest 25% attained ILOA scores
that ranged from 26-40. Descriptive statistics on the independent and dependent variables for all subjects are presented in table 2.

A two-way analysis of variance (ANOVA) was conducted to examine possible differences in students’ scientific reasoning abilities relative to informal learning environments (impoverished, enriched) and classroom teaching procedures (non-inquiry, inquiry) and the interaction of these two variables. Table 3 shows that the main effect of informal learning environment yielded a significant F ratio \((p < 0.01)\). Students with enriched informal learning environments scored significantly higher on the CTSR than students with impoverished informal learning environments. The main effect of teaching procedure also indicated a statistically significant F ratio \((p < 0.01)\). Students in science classes taught by inquiry scored significantly higher on the CTSR compared to those in science classes taught through non-inquiry teaching procedures. There was no significant interaction between learning environment and teaching procedure.

For interpretation, students’ mean CTSR scores relative to mean ILOA scores and teaching procedures have been plotted on the graph shown in figure 1. The graph reveals that in both non-inquiry and inquiry classrooms, students with high ILOA scores averaged higher CTSR scores than students with low ILOA scores. Figure 1 also shows a general increase in CTSR scores for students in inquiry classrooms, which was apparent for students scoring high on the ILOA and for students scoring low on the ILOA. Thus, figure 1 shows that inquiry teaching procedures benefited both the high ILOA group and the low ILOA group.

Table 2. CTSR and ILOA data for all subjects \((n = 505)\).

<table>
<thead>
<tr>
<th>Source</th>
<th>CTSR</th>
<th>ILOA</th>
</tr>
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<tr>
<td></td>
<td>(n)</td>
<td>Range</td>
</tr>
<tr>
<td>Low ILOA</td>
<td>242</td>
<td>0-12</td>
</tr>
<tr>
<td>High ILOA</td>
<td>263</td>
<td>0-12</td>
</tr>
<tr>
<td>Non-inquiry</td>
<td>295</td>
<td>0-12</td>
</tr>
<tr>
<td>Inquiry</td>
<td>210</td>
<td>0-12</td>
</tr>
<tr>
<td>Low ILOA × Non-inquiry</td>
<td>140</td>
<td>0-12</td>
</tr>
<tr>
<td>Low ILOA × Inquiry</td>
<td>102</td>
<td>0-11</td>
</tr>
<tr>
<td>High ILOA × Non-inquiry</td>
<td>155</td>
<td>0-12</td>
</tr>
<tr>
<td>High ILOA × Inquiry</td>
<td>108</td>
<td>0-12</td>
</tr>
</tbody>
</table>

Table 3. Two-way analysis of variance with CTSR score as the dependent variable.

<table>
<thead>
<tr>
<th>Source</th>
<th>(SS)</th>
<th>(df)</th>
<th>(MS)</th>
<th>(F)</th>
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<tbody>
<tr>
<td>Learning Environment (A)</td>
<td>234.62</td>
<td>1</td>
<td>234.62</td>
<td>30.44*</td>
</tr>
<tr>
<td>Teaching Procedure (B)</td>
<td>75.23</td>
<td>1</td>
<td>75.23</td>
<td>9.76*</td>
</tr>
<tr>
<td>A × B</td>
<td>0.49</td>
<td>1</td>
<td>0.49</td>
<td>0.063</td>
</tr>
<tr>
<td>Error</td>
<td>3861.82</td>
<td>501</td>
<td>7.71</td>
<td></td>
</tr>
</tbody>
</table>

Note: *\(p < 0.01\)
Discussion

The findings of this study indicate that enriched informal activities outside the classroom correspond to higher scientific reasoning abilities among students. Since reasoning ability is an important skill for science learning, these informal activities likely impact students' achievement in the formal classroom setting. As Adey and Shayer (1990) described, this may be due to the more developed schemata of those students with an enriched experiential background, which allows them to more easily assimilate and understand formal classroom information than their student counterparts with lesser-developed schemata. The findings would support the continued development of a wide range of school and community activities that involve students in informal learning experiences. Students' involvement in scouting, 4-H, volunteer groups, hobbies, intramural sports, and partnership activities between the school and community resources (e.g. businesses, industries, museums, natural areas) may provide experiences that stimulate cognitive conflict and promote social interaction that improve their scientific reasoning abilities.

This study also revealed that students had higher reasoning abilities in inquiry classrooms versus non-inquiry classrooms (table 3). This finding may be attributed to the experiential nature of inquiry teaching. Inquiry teaching procedures that involve students in data gathering through direct experience with materials, and frequent social teaming to evaluate and present findings, also promote reasoning abilities. In contrast, non-inquiry-teaching procedures, which limit student involvement, likely result in lesser gains in students' reasoning ability. The results of this study support the findings of previous studies indicating that students experiencing inquiry science instruction showed enhanced scientific reasoning abilities (Boulanger 1981, Wise and Okey 1983, Renner and Marek 1990, Lawson 1995a, Marek and Cavallo 1995). Since students in classrooms where inquiry teaching was the norm in this study, also had improved reasoning abilities, future research should examine the questions of this investigation from a more

Figure 1. Graphic representation of interaction groups.
causal perspective. For example, might inquiry teaching help students compensate for impoverished learning environments in terms of reasoning ability? A response to this question would have important implications on current teaching practices in science.

The findings associated with informal learning further the work of other researchers investigating the nature of students’ science experiences outside the formal classroom (LaBelle 1982, Maarschalk 1988, Zuzovsky and Tamir 1989, Tamir 1990, Lucas 1991, Dierking and Falk 1994, Alsop and Watts 1998, Jones 1998, Korpan et al. 1998). This previous work was extended through the examination of these informal learning activities in the context of different science classroom teaching procedures to determine their effects on scientific reasoning abilities. Also, findings from this study are the result of a more comprehensive evaluation of students’ informal learning environments and not only those activities considered science-related. Thus, unlike previous informal learning studies (Korpan et al. 1998; Maarschalk 1988, Zuzovsky and Tamir 1989, Tamir 1990) that primarily examined student activities identified as scientific (e.g. watching educational television, visiting museums), this study included activities not traditionally regarded as scientific (e.g. working outside the home, participating in sports). This study expanded the view of informal learning to include any activity providing cognitive conflict and/or social interaction. Both science and non-science oriented informal learning provide experiences consistent with the constructivist philosophy and thus promote scientific reasoning abilities among students.

The findings of this study generally reveal the importance of rich, informal learning activities and inquiry-oriented formal classroom teaching procedures to scientific reasoning abilities. An enriched informal learning environment coupled with inquiry teaching procedures in the formal classroom environment provide students with numerous opportunities for the direct experiences, cognitive conflicts and social interactions that develop scientific reasoning abilities. Furthermore, students with high scientific reasoning abilities will become more scientifically literate adults, better able to make informed personal decisions as well as contributions to society.

**Educational implications**

Science education researchers frequently acknowledge the effect of out-of-classroom experiential learning in research outcomes. However, this aspect of learning and the activities that facilitate this learning are often overlooked in educational research. The fact that nearly 85% of students’ time is spent outside the formal classroom (Medrich et al. 1982) means the learning taking place during this time is potentially significant. While most groups of students in this study benefited from inquiry teaching procedures, students from situations with limited informal learning opportunities may especially benefit from an inquiry teaching approach. It is speculated that it may be possible to compensate for an impoverished informal learning environment via inquiry teaching in the formal learning environment. As mentioned earlier, future research needs to thoroughly address this possibility.

The benefits of participating in informal activities extend beyond the development of reasoning abilities. Resnick (1987) identified four broad categories of learning that take place in out-of-school activities compared to life in school. First,
most out-of-school activities require students to be part of a socially functional group. Work and play is usually accomplished in social settings and thus the development of these interactive skills comes as a result of participating in informal activities. By contrast, most activities within school, such as worksheets and questioning, are designed as individual work. Second, out-of-school activities make extensive use of tools that shape and facilitate the cognitive activity taking place. In contrast, in-school activities place a premium on ‘pure thought’ or the ability to memorize (especially in testing situations) that require students to work without the support of tools, such as books or calculators, that may facilitate thinking. In contrast, third, actions outside school are connected with objects and events in context with the activity at hand. Students learn ‘practical mathematics’ that can be applied to everyday situations (e.g. stock market numbers, carpentry or construction site mathematics, sports statistics). In-school mathematics activities generally require students to engage in symbol manipulation detached from any referents. Rules are learned but this knowledge is disconnected from real life situations. Fourth, schooling teaches general skills and knowledge that are hopefully transferable to outside school. Unfortunately, evidence suggests that very little in-school knowledge is transported to out-of-school use (Resnick 1987). Informal activities, in which situation-specific competencies are developed, dominate those encountered by students outside school. Students are able to learn a broad range of situation-specific skills by engaging in numerous informal activities that expose them to varied situations.

From a practical standpoint, teachers can encourage students to become involved in extracurricular activities associated with the school and community. Suggestions from teachers that students become involved in the Student Council, the yearbook, a science club, or a sports team could be influential in persuading students to join such groups. Participation in intellectually and socially instructive activities may stimulate the development of logical thinking skills useful to students’ future careers and everyday life.

With an understanding of the importance of out-of-school activities, teachers can encourage home-centred activities that may actively involve parents as facilitators in their child’s learning. Such methods of involving parents include; contracts with parents that specify a particular role for parents to play in classroom assignments and activities; encouraging parent-student interaction through classroom assignments (e.g. developing a chart of the physical characteristics of family members for the study of inherited characteristics); inviting parents to become more involved in their child’s daily activities outside of school and; educating parents about the importance of informal activities outside of school on students’ development of reasoning abilities.

Along with teachers, parents play a key role in the activities that engage students outside the classroom. To facilitate the development of scientific reasoning abilities in their children, parents can; monitor the study habits of their children; encourage reading and creative activity such as music and art; provide opportunities to learn outside the school (e.g. visiting museums, zoos, cultural events); encourage participation in extracurricular activities at school and in the community; discuss current international, national and local events; establish chores around the home for children to complete (e.g. taking care of pets, mowing the lawn, assisting in the preparation of meals) and; encourage children to find a hobby (e.g. photography, model building, gardening). Such activities will likely
benefit children in many ways, one of which is to improve their ability to learn science in school. Perhaps most important, however, is that the development of children's scientific reasoning abilities can help them become lifelong learners and more productive, informed citizens of our society.

Limitations

This study was a first, exploratory investigation of the impact out-of-school activities and inquiry teaching may have on students' scientific reasoning abilities. Though clear patterns emerged, future research should follow up on these patterns through perhaps, intensive case studies. More effort can be made in future studies to examine the specific kinds of informal experience that most translate to higher reasoning abilities. Also, more in-depth analyses of other aspects of science learning, in addition to reasoning ability, are needed. For example, this study did not explore students’ content understanding, nor their future college and career goals. It would be relevant to examine how out-of-school experiences may have contributed to students’ understanding of certain science content or processes, or how informal learning experiences may have influenced their future college or career decisions.

References


HALL, G. S. (1907) *Aspects of Child Life and Education* (Boston: Ginn & Company).


