Does Waldorf Offer a Viable Form of Science Education?

A Research Monograph

by

David Jelinek, Ph.D. and
Li-Ling Sun, Ph.D.

College of Education
California State University, Sacramento
6000 J. Street
Sacramento, CA 95819
djelinek@csus.edu
lsun@csus.edu

Acknowledgements

This work was made possible in large part by a Grant from the Center for Ecoliteracy. Our thanks go to Peter Buckley for making the grant possible. Thank you also to Margo Crabtree for conducting the preliminary investigations that addressed the need to conduct a study of this magnitude; to Pierre-Yves Barbier for overseeing the survey administration, and to the hundreds of Waldorf educators and students who participated in surveys and interviews and/or graciously allowed us into their classrooms. Thanks also go to Kendall Zoller, Laura Beck, Amy Buckley and Jeff Baldwin for their in depth evaluations of the Waldorf science curriculum. Finally, thank you to Jayne Speich for editorial assistance and to Shanti Jelinek for hundreds of hours writing, transcribing, coding, collecting and entering data.

ABSTRACT

This monograph reports the findings from a multifaceted study undertaken to address the strong need for empirical evaluation of Waldorf education. There is growing interest in the Waldorf method among many parents and educators because they believe it more successfully engages students and supports meaningful learning than do mainstream methods. Yet these parents and educators have little first-hand knowledge of Waldorf pedagogical principles or the founding father's philosophy. Increasingly, they find themselves caught between the extremes in a debate others have long-engaged over Waldorf education: a debate that can be summarized at one extreme as adamant opposition to the peculiar philosophical background of Rudolf Steiner, whose beliefs, critics claim, constitute "pseudo-science;" and at the other extreme as a firm conviction that any shortcomings in student achievement under Waldorf methods is the result of shortcomings in implementation of the Waldorf curriculum as intended – and decidedly not because the curriculum is "pseudo-scientific."

The purpose of this study was to use recognized and accepted methods of inquiry and investigation to uncover the nature of Waldorf science education and to evaluate its applicability to mainstream science education. The study began with four primary questions: (1) How does the Waldorf science curriculum align itself with state and national science standards? (2) What are the perspectives of Waldorf students, teachers, and parents regarding science education in the Waldorf context? (3) How do Waldorf students' scientific reasoning and problem solving skills compare to those of their counterparts in mainstream educational settings? (4) Does Waldorf offer a viable form of science education?

The findings of the study are reported in four sections. First, it provides a theoretical framework by analyzing Waldorf Theory relative to the theories of Experiential Learning, Developmentalism, ZPD (Vygotsky), Spiral Curriculum, Triarchic Intelligence, and Multiple Intelligences. Second, it analyzes the Waldorf science curriculum through document analysis, external reviews, and field testing of Waldorf curriculum materials. Third, it analyzes results of interviews and a national survey administered to Waldorf educators. Fourth, it analyzes findings from various logical reasoning and scientific problem-solving tasks administered to Waldorf students, then the results of videotaped Waldorf science lessons.

A concluding discussion examines the research questions in light of the data, with a particularly strong focus on the question of whether or not Waldorf offers a viable form of science education, and if not, what could be done to make it so?

TABLE OF CONTENTS

Introduction 1

Chapter 1 Theoretical Framework 3

Chapter 2 Methods Overview 9

Chapter 3 Curriculum & Assessment 18

Chapter 4 Surveys & Interviews 26

Chapter 5 In the Classroom 34

Chapter 6 Discussion of the Findings in Relation to the 4 Research Questions

1. *How Does the Waldorf Science Curriculum Align Itself with State and National Science Standards?* 49
2. *What Are the Perspectives of Waldorf Students, Parents and teachers Regarding Science Education in the Waldorf Context?* 51
3. *How do Waldorf Students' Scientific Reasoning and Problem Solving Skills Compare to Those of Their Counterparts in Mainstream Educational Settings?* 56
4. *Does Waldorf Offer a Viable Form of Science Education?* 58

Chapter 7 How Could Waldorf Offer a Viable Form of Science Education? 62

Conclusion 71

References 72

Appendix The Waldorf Science Curriculum 77

LIST OF TABLES

Table 1	Data sources, Procedures and Analysis	17
Table 2	Descriptive Statistics for Pedagogical Appropriateness	19
Table 3	Descriptive Statistics for Science Content	20
Table 4	Descriptive Statistics for Presentation & Format	21
Table 5	Representative Narrative Evaluations on Pedagogical Appropriateness	22
Table 6	Representative Narrative Evaluations on Science Content	23
Table 7	Representative Narrative Evaluations on Presentation & Format	25
Table 8	Representative Statements on Knowing What to Teach	27
Table 9	Representative Statements of What is Important to Teach	29
Table 10	Representative Statements on confidence in Teaching Science	30
Table 11	Representative Statements on Assessment	32
Table 12	Representative Statements from Interview Data	32
Table 13	Subjects for the Verbal Logical Reasoning Task	37
Table 14	Scoring Scheme for the Protocol Items 17-19	37
Table 15	The Constructivist Learning Model	38
Table 16	Mean Performance on Verbal Logical Reasoning Task	39
Table 17	Comparison Scheme for t-test	39
Table 18	Within group t-test (paired) – Compare Syllogism & Inference	39
Table 19	Between group t-test (paired) – Compare Syllogisms	39
Table 20	t-test paired (within group) – Compare Inferences	39
Table 21	t-test paired (within group) – compare Overall Performance	40
Table 22	Mean Comparison of Performance for Public School & Waldorf Groups	40
Table 23	Comparison of Protocol Items Responses (%)	40
Table 24	Average Correct Rate for Each Item Group	41
Table 25	TIMSS Magnet Results	41
Table 26	Sample Student narrative Responses to TIMSS Magnet Task	43
Table 27	Inquiry Analysis Statistics	44
Table 28	Mean Ratings of 4 Comparison Classes	44
Table 29	Correlations of Inquiry Categories	45

LIST OF FIGURES

Figure 1	Theoretical Framework	3
Figure 2	Comparisons of Mean Percentages for Pedagogical Appropriateness	20
Figure 3	Comparisons of Mean Percentages for Science Content	21
Figure 4	Comparisons of Mean Percentages for Presentation and Format	22
Figure 5	Knowing What to Teach	27
Figure 6	What is Important to Teach	29
Figure 7	Confidence in Teaching Science	30
Figure 8	Assessment	31
Figure 9	Tasks and Problem Solving Strategies	34
Figure 10	Comparison Scores of Percent Choosing Correct Magnet	42
Figure 11	Comparison of Percent Providing at least 1 Correct Magnet Solution	42
Figure 12	Percentage of Instructional Time per Inquiry Categories	44
Figure 13	Percentage of Time Each Class Devoted to "Invitation"	45
Figure 14	Percentage of Time Each Class Devoted to "Exploration"	45
Figure 15	Percentage of Time Each Class Devoted to "Explanation"	46
Figure 16	Percentage of Time Each Class Devoted to "Taking Action"	46
Figure 17	Invitation – Time Devoted to Each Category	47
Figure 18	Exploration – Time Devoted to Each Category	47
Figure 19	Explanation – Time Devoted to Each Category	48
Figure 20	Action – Time Devoted to Each Category	48

Introduction

Rudolf Steiner started the first Waldorf School more than eighty years ago for the children of workers at the Waldorf Astoria Cigarette Factory in Stuttgart, Germany. The lectures and discussion sessions he conducted with the school's first teachers, combined with a curriculum outline based on Steiner's view on the nature of human development, were and remain the cornerstone of Waldorf education. Viewing the teacher as an artist and the classroom a living canvas upon which the teacher-artist would render breathtaking creations, Waldorf education infused war-torn Germany with a new view of the classroom where students engaged in artistic activities and got out of their seats to learn. Waldorf education expanded rapidly in Europe, then the United States, where it continues to flourish today.

A relatively new twist to the Waldorf expansion is the introduction of its methods into mainstream public school settings. This heightens its visibility and raises many questions about its viability. Is its approach to teaching and learning science, for example, sound and valid, and how do we know? Hitherto anecdotal evidence has attested to Waldorf's effectiveness, substantiated occasionally with an internal Waldorf study, but hardly representing empirical authenticity. Waldorf studies to date have generally taken the form of "proof" generated by Waldorf advocates or diatribes by disenchanted parents whose children were "wronged." In either case the lack of empirical evidence has limited the potential significance of the findings.

This study was undertaken to address the strong need for empirical evaluation of Waldorf education. There is growing interest in the Waldorf method among many parents and educators because they believe it more successfully engages students and supports meaningful learning than do mainstream methods. Yet these parents and educators have little first-hand knowledge of Waldorf pedagogical principles or the founding father's philosophy. Increasingly, they find themselves caught between the extremes in a debate others have long-engaged over Waldorf education: a debate that can be summarized at one extreme as adamant opposition to the peculiar philosophical background of Rudolf Steiner, whose beliefs, critics claim, constitute "pseudo-science;" and at the other extreme as a firm conviction that any shortcomings in student achievement under Waldorf methods is the result of shortcomings in implementation of the Waldorf curriculum as intended – and decidedly not because the curriculum is "pseudo-scientific." The polarity of this debate, coupled with the unreliability of other sources of information about Waldorf teaching methods, fails to serve those who are intrigued by the methods and their apparent success, but unable to quantify whether they really work.

The purpose of this study was to use recognized and accepted methods of inquiry and investigation to uncover the nature of Waldorf science education and to evaluate its applicability to mainstream science education. The study drew upon a variety of professional and lay perspectives within the academic community, mainstream education, and the Waldorf movement. Overall, the focus was on gaining an understanding of Waldorf's perspective of knowing and doing science and on placing the findings within the broader context of mainstream science education.

Research Questions

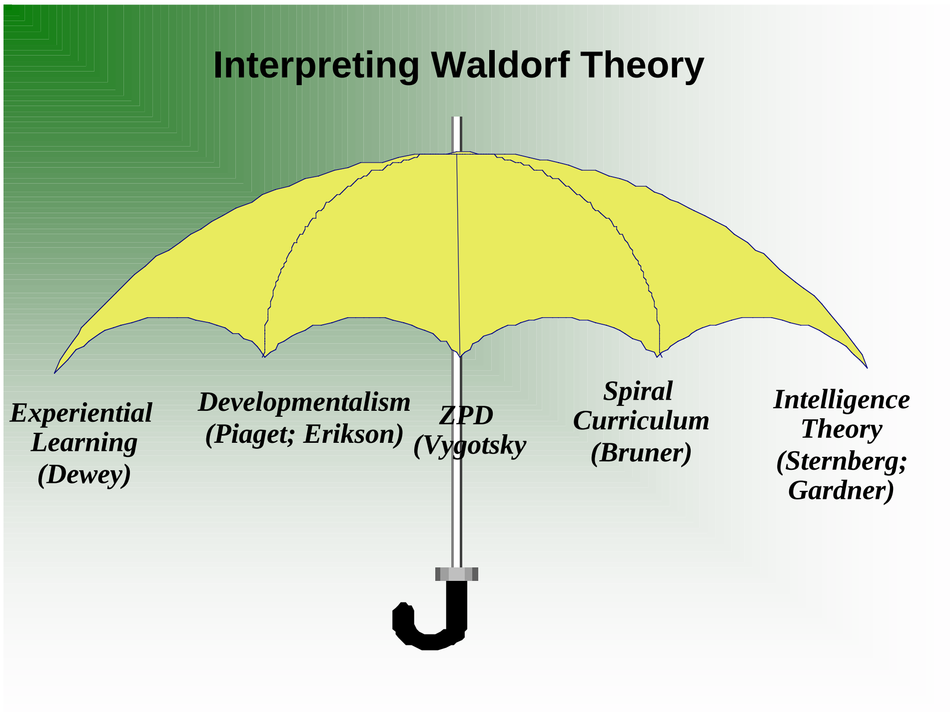
The four research questions of the study were:

1. How does the Waldorf science curriculum align itself with state and national science standards?
2. What are the perspectives of Waldorf students, teachers, and parents regarding science education in the Waldorf context?
3. How do Waldorf students' scientific reasoning and problem solving skills compare to those of their counterparts in mainstream educational settings?
4. Does Waldorf offer a viable form of science education?

CHAPTER 1

Theoretical Framework

Figure 1. Theoretical Framework



Before investigating Waldorf education, we sought to find a conceptual basis by which to interpret it –an "umbrella" of well-grounded theories that would allow us to draw upon many empirical studies and make inferences about parallel aspects to Waldorf.

Experiential Learning Theory, the first of the theories we considered, has its roots in the work of John Dewey, who contended that people solve problems by conducting inquiries. Dewey's theory was adopted by the Progressive educational movement of the 1930s and eventually evolved into the Constructivist reform movement in the 1990s (Kraft & Kielsmeier, 1995; Prawat, 1995). Dewey argued that an "organic connection between education and personal experience" (John Dewey, 1938) was necessary to guide practice, and he advanced a perspective that synthesized both theory and practice. He advocated free activity versus external discipline, learning through experience as opposed to learning from texts, and acquisition of skill in context rather than in isolation or by drill (p. 20). Logic, rationality, the scientific method, and discovery of intrinsic meanings signify important elements of Dewey's philosophy (Dewey, 1930; John Dewey, 1938).

It might be said that Steiner anticipated Dewey's experiential learning theory. Like Dewey, Steiner strove to educate the child from a base of experience and activity first (primary experience), followed later by a conceptualization (reflective experience). Steiner also placed an emphasis on proceeding from the whole to the parts – a method that remains a guiding principle in current Waldorf pedagogy. For example, mineralogy might be taught by a grand picture of the granite mountains before considering the finer components; or a chemistry lesson might begin by observing the process of burning, transitioning to simple chemical concepts (Stockmeyer, 1965). Steiner argued that the first science lessons should be observational, not theoretical (Harwood, 1958).

Steiner further believed in engaging a child's imagination as part of the primary experience preceding conceptualization, and that the way to do this is through art. His address to the first Waldorf teachers in 1921 still guides the Waldorf teaching process today: "We must still make the lifeless things live through imagination and always connect them with real life. It is possible to connect all the phenomena of physics with real life, but we ourselves must have imagination in order to do it " (Steiner, 1919,1976). Ultimately, a primary imperative for Waldorf education is that the imagination should hold sway!

Thus, Waldorf students are introduced to science phenomena through art, via their imaginations. Beginning with a phenomenological approach to zoology, botany, geology, and physics, the Waldorf teacher provides the child with imaginative and artistic opportunities in order to exercise critical observation techniques, followed by contextual experiences of the phenomena, with teacher guidance through the reflective process, leading to eventual concept formation (Steiner,1967; Harwood,1958). For example, modeling clay figures becomes a means to critically observe animal forms, drawing foliage a way to study leaf characteristics, and creating and playing stringed and wind instruments a method to study principles of acoustics (Stockmeyer, 1965; Steiner, 1972).

In effect, then, Dewey's ideas about experiential learning are reflected in the Waldorf pedagogy through the mechanism of art, so that both imagination and direct, personal, "real-life" experience become the foundation for conceptual learning. Steiner said, "This is the essential thing, to begin with real life in considering the different phenomena of the physical and mineral world. If you do it the other way ... the lesson soon makes him tire. He does not get tired if you start from real life." (Steiner, 1967).

Developmentalism is a fundamental basis for the Waldorf pedagogy, and studies have been conducted comparing Steiner's developmental theory to Piaget and others (Steiner, 1919,1976; Piaget 1931; Bruner 1971; Piaget 1973;Elkind,1981). Like Piaget, Steiner's theory argues that the pedagogy should be aligned with developmental characteristics so that age-appropriate activities are introduced in a manner conducive to the child's levels of physical, emotional, and mental maturation. But Piaget and Steiner part company on the basis for developmental stages, for Piaget's basis is cognitive, and Steiner's is philosophically spiritual.

Steiner argued that the child's age parallels advancing degrees of consciousness incarnating in the physical body, and that the teacher's role is to guide proper incarnation through correct and specifically selected pedagogical content. For example, according to Waldorf developmentalism, younger children in the early grades should focus on "wholes" rather than "parts." Later, a child begins to feel the breaking up of knowledge into specialized departments, which enables him or her to relate to "parts." Hence, this version of developmentalism guides both method and content. Subjects such as nutrition and physiology, comparing and contrasting sources of starch, sugar, protein, and fat – "parts" -- would not be taught until grades seven or eight (Harwood, 1958; Stockmeyer, 1965). The concept of cause and effect is another example. Waldorf holds that these concepts should not be taught before the age of eleven because the child has experienced little internal understanding by which to discern genuine meaning (Stockmeyer, 1965).

In practical terms, the Waldorf style of developmentalism, in the context of a Waldorf school, often introduces science subjects in later grades than the same subjects would be introduced in mainstream science curricula, with obvious implications for a comparison to state and national standards. Piaget's developmentalism, by contrast, would not necessarily time the introduction of specific content by developmental stage, but rather would guide the method by which the content is presented to children of different ages and developmental stages.

The Zone of Proximal Development (ZPD) (Vygotsky, 1978) in some ways parallels Steiner's view that the adult should be a central presence in the classroom (Steiner, 1967). Much of Vygotsky's work singled out the dynamic social environment in which students interact with one another and with teachers. This resonates in Waldorf methods, where teachers are specifically trained to recognize a child's social orientation and to understand the pedagogical possibilities available to lift the child to a new level of activity and consciousness, given his or her social orientation.

Vygotsky asserted that the ZPD is the difference between what a child can do on his or her own, and what he or she can do with the help of an adult. By reaching into the child's "zone," an adult – the teacher – can create a structure, or scaffold, to support the child in being able to increase what he or she can do. When learning is situated or contextualized – context or situation being provided by the teacher through instructional strategies such as questioning and problem-solving to act as the scaffold -- it invites more meaningful learning components to occur. (Barnes, 1976; Engel, 1995; Kintsch, 1989; Norman & Schmidt, 1992; The Cognition and Technology Group at Vanderbilt, 1990). Vygotsky elaborates:

> Before you want to involve the child in some kind of activity, interest the child in it, being concerned to make sure that the child is ready for this activity, that all the child's strengths needed for it are exerted, that the child will act for him/herself, and that for the teacher remains only the task of guiding and directing the child's activity (Vygotsky, 1926,1991).

Indeed, in Waldorf classrooms the teacher orchestrates frequent scaffolding techniques. For example, starting in first grade students regularly recapitulate stories and details of previous lessons, with each recapitulation raising the bar for accuracy and completeness. This process is also exemplified in science lessons where students are asked to describe, write, and illustrate experiments which were demonstrated the previous day (Trostli, 1995b).

The Spiral Curriculum emerged out of Jerome Bruner's leadership in the Woods Hole Conference of 1959, and from his classic *The Process of Education* (Bruner, 1960), which gave rise to the human development theme in science education. Bruner, like Steiner, contended that an emphasis on too much academic learning was counterproductive to the development of critical thinking faculties because it emphasized pre-selected and pre-designed materials, such as worksheets and step-by-step activities, over "figuring out how to use what you already know in order to go beyond what you already think" (Bruner, 1983). Part of the problem of overly prescriptive educational methods is the tendency to feed too much conceptual information to students at one time. Bruner argued that there is a basic "structure" to each concept which should be revisited by the child again and again over time, because as the child develops, so will the structure of the concept. In other words, the child will gain an ever-deepening understanding of the concept provided it is not prematurely drilled into his or her brain. Like points on a spiral, the concepts come around again, gaining momentum in complexity and meaningfulness as they do so.

It would be incorrect to say that Rudolf Steiner advocated a spiral curriculum for all the same reasons Bruner did, but some similarities exist. Direct conceptual teaching is delayed in Waldorf, especially scientific concepts because, in Steiner's words, "The true aim of education is to awaken real powers of perception and judgment in relation to life and living. For only such awakening can lead to true freedom "(Steiner, 1922, 1972). He continues: "A great deal is said today about the need for engineers and scientists, and the point of view is taken that if you have better science courses and specialize sooner in the scientific branches of knowledge, you are going to get better scientists. I think that the best scientist is the best and most creative thinker and the task of education is first of all to educate human beings who then become scientists." You educate human beings, according to Waldorf pedagogy, by fostering the imagination and developing the will. These qualities, or "capacities" as they are often called in Waldorf pedagogy, might be considered analogous to Bruner's basic "structure". And like Bruner's structure, Waldorf's "capacities" will spiral around again, taking on greater momentum and intellectual significance commensurate with the child's developmental level.

Intelligence Theories, particularly Robert Sternberg's Triarchic Intelligence Theory (Sternberg, 1997) and Howard Gardner's Multiple Intelligences Theory (Gardner, 1993), provide another lens through which to consider Waldorf.

Sternberg distinguishes among three basic kinds of thinking – analytical, creative, and practical and asserts that the successful *transfer* of knowledge from one particular context to another is dependent upon integration of all three types of thinking. Gardner's Multiple Intelligence (MI) theory is in some ways an expanded version of Sternberg's theory, comprising eight "intelligences": logical-mathematical, linguistic, musical, spatial, bodily-kinesthetic, interpersonal, intrapersonal, and naturalist.

Both Sternberg's and Gardner's theories are preceded by Steiner's turn-of-the-century theory that human thinking is characterized by a complex interaction of feeling, willing, and thinking; and that for cognitive development to unfold, methods must be employed to activate all three conditions (Steiner, 1919,1966). This view is the basis for Waldorf's emphasis on the arts (to activate the "feeling life"), movement (to activate the "willing life") and imagination (to activate the "thinking life") (Harwood, 1958; Querido, 1982; Steiner, 1919,1976).

When Gardner's MI theory emerged in 1983, Waldorf advocates were quick to point out that Gardner was affirming what they had been saying all along, that human intelligence is comprised of multiple variables traditionally discredited by cognitive psychologists. Sternberg's theory, though less popular, further underscores this position.

While obvious parallels of educational implications from these three theories of intelligence exist, that is really where the similarities stop. Steiner's rationale for his theory of human intelligence is derived from perspectives he claims to have gained from clairvoyant investigations in the spiritual world. In spite of such unconventional claims, it can be said that in many ways, the work of Gardner and Sternberg arrived at a more conventional rationale and basis for many of the same ideas – although Gardner, originally complimentary about the consistency between Waldorf's theory of intelligences and his own theory of multiple intelligences, has sought to distinguish himself from the Waldorf community as a whole and provided the following message via email to the webmaster for People for Legal and Nonsectarian Schools (PLANS), a Waldorf critics website (Bonhiver, 2002):

> Here is a brief note that you have my permission to circulate PROVIDED THAT YOU CIRCULATE THE STATEMENT IN FULL:
>
> I have not been a student of Waldorf Education but have known about it for many years and have praised some of its aspects and features. I have also been uncomfortable with some of the esoteric and pseudo-scientific concepts that Rudolf Steiner put forth. It has recently come to my attention that representatives of the Waldorf movement have discouraged open debate about the merits and flaws in the Waldorf approach. Such silencing --if true-- is deplorable and calls into question the credibility of current representatives of the movement. I encourage totally open public debate about the Waldorf approach -- all parties will benefit from such discussion. At the same time I must note that there are skilled as well as poor examples of every educational innovation -- Montessori, Waldorf, Dewey, Sizer etc-- and it is a mistake to judge an entire movement by only its worst, or only its best, instantiations.

It is in the spirit of “totally open public debate about the Waldorf approach” that this paper is submitted. As the study will bear out, there are some challenging questions that need to be addressed, but also some compelling evidence that Waldorf has made significant educational impacts; hopefully the evidence that follows will provide substance for the debate.

CHAPTER 2

Methods Overview

This project lays the groundwork for empirical investigation using both qualitative and quantitative methodology. We feel that the primary strength of the study is that we were able to overcome a past pattern of resistance to external study on the part of the Waldorf community, a pattern that had previously stymied research efforts. Several of our researchers had prior Waldorf experience and were familiar with the culture and language they encountered. We also took pains to obtain the endorsement of leaders in the Waldorf field, and we conducted numerous informal meetings before data collection began in order to demonstrate a sincere commitment to a fair treatment of Waldorf methods.

At the same time, we rigorously guarded against researcher bias by adhering to widely accepted and well-defined data collection and analysis methods, and by bringing in researchers and assistants with no Waldorf background. We used multiple methods to collect a variety of perspectives of interpretations, and our statistical testing included measures of central tendency, variability, frequency distributions, correlations, regression, t-tests and chi-square. Qualitative analysis relied on Constant Comparative Analysis (CCA) (Strauss, 1987). Ultimately, our findings are supported by the integrity of the methodology, by the openness and repetitiveness of the process, and by the unbiased expertise of our research team. The quality of the evidence will, we hope, provide substance for the continued debate over the appropriateness of Waldorf methods outside the confines of the Waldorf community.

To accommodate the multifaceted nature of this study and the need to analyze different kinds of data in varied ways, we broke the overall Waldorf Science Study into the three subordinate studies: (a) Curriculum & Assessment, (b) Surveys and Interviews, and (c) In the Classroom. An overview and relevant literature for these three subordinate studies are provided below.

Curriculum and Assessment

The purpose of the *Curriculum & Assessment* component of this study was to formulate an accurate picture of the Waldorf science curriculum, then to evaluate it and related materials against criteria generally accepted by the science education research community.

Relevant Literature. As made evident in the *theoretical framework*, Waldorf pedagogy is strongly influenced by Rudolf Steiner's philosophical perspective and it would be easy to get sidetracked into an analysis and critique of that perspective. Indeed, others have done so, most notably in the web-based critiques accessed through the website of People for Legal and Nonsectarian Schools (PLANS) http://www.waldorfcritics.org. In preparation for this study hundreds of pages of the online criticisms were reviewed, as well as literature by noted skeptics who have raised legitimate arguments about the viability of Rudolf Steiner's and Waldorf's pedagogical positions. Numerous Waldorf responses to the criticisms were also reviewed and Waldorf educators were interviewed to gain their perspective. The intent of this section, however, is to acknowledge the resources that inform Waldorf science pedagogy and to leave the debate for another venue.

Based on a thorough investigation of available literature and resources in the Waldorf movement, the most comprehensive picture of the Waldorf science curriculum is still derived from Rudolf Steiner's conceptualization during the developing year of Waldorf education in the early 20th century (Hutchins, 1966, 1984). These conceptualizations have, however, been interpreted and recast in a number of ways by current Waldorf educators (Baravalle, 1974; Bojarsky, 1999; D'Aleo & Edelglass, 1999; Edelglass, Maier, Gebert, & Davy, 1997; Grohmann, 1999; Julius, 2000; Petering & Mitchell, 2000; Trostli, 1995a; Wilkinson, 1978a). The Waldorf science curriculum that was drafted for this study is derived from Steiner's curriculum teachings and these resources, plus unpublished Waldorf school curriculum documents. It is organized by grade levels into five categories: (1) From *The Curriculum of the First Waldorf School* (Rudolf Steiner); (2) Overview; (3) Objectives; (4) Topics (Subjects); and (5) Strategies. No doubt there will be Waldorf educators that argue this still does not capture the essence of Waldorf science education, because Waldorf is not about objectives or topics or strategies; it is about "means to an end…. Developing the life of feeling….of thinking….of willing" (Trostli, 1995b). Nevertheless, the curriculum had to be organized in a fashion that a number of people could read, including non-Waldorf educators.

In addition to Waldorf school curriculum materials, other printed material that informed the Waldorf Science Curriculum included: *The Curriculum of the First Waldorf School*, edited by Eileen Hutchins; *Physics is Fun,* by Roberto Trostli; *Sensible Physics Teaching* by Michael D'Aleo & Stephen Edelglass; *Plant Study, b*y Roy Wilkinson*; The Living World of the Plants,* by Gerbert Grohmann*; Nutrition-Health-Anthropology,* by Roy Wilkinson; *Astronomy -- an Introduction*, by Hermann von Baravalle; *Fundamentals for a Phenomenological Study of Chemistry,* by Frits Julius; and *Demonstration Manual for Use in the Waldorf School 8th Grade Chemistry Main Lesson.,* by Mikko Bojarsky.

As a framework to evaluate the curriculum "Criteria for Selecting Inquiry-based Science Curriculum Materials" (The National Academy of Sciences, 1997,2000). Based on generally accepted principles aligned the National Science Education Standards (NSES), this document outlines three sets of criteria to evaluate science curriculum materials: (1) *Pedagogical Appropriateness*, encompassing "strategies for building conceptual understanding, teaching science as inquiry, and applying effective instructional strategies" (p. 75); (2) *Science Content*, encompassing currency, accuracy, consistency with science standards, and appropriate treatment of content; and (3) *Presentation and Format*, encompassing clarity, instructional delivery, and appropriate strategies for diverse populations. For purposes of this study the criteria for each of these three categories were developed into a rubric using a 5 level Likert scale that evaluates the degree to which the criteria have been met, from "Insignificantly" to "Extensively".

Surveys and Interviews

The purpose of this component of the study was to gather perspectives from within the Waldorf community itself by a national Waldorf teacher survey, by focus groups, and by interviewing individual Waldorf teachers. Our primary intention was to gather sufficient data to answer the third research question: "What are the perspectives of Waldorf students, teachers, and parents regarding science education in the Waldorf context?" A secondary intent was to gather data that might contribute responses to the first and second research questions regarding the viability of Waldorf science education and alignment with standards.

Relevant Literature. We used the metacognitive theoretical perspective as our foundation for the interview and survey protocols used in the study. Metacognition is appropriate because it encompasses the same variables on which this study is focused: affective, cognitive and behavioral factors (Hunt, Frost, & Lunnenborg, 1973; Marzano et al., 1988; Sternberg & Spear-Swerling, 1996). For purposes of this study, we define affective factors as Waldorf teacher attitudes, interest, commitment, and attention to teaching science; cognitive factors as understanding of scientific concepts, principles and processes of knowledge acquisition and knowledge production.; and behavioral factors as teaching and learning perspectives such as evaluation, planning, and the promotion of critical thinking (Ennis, 1985; Goodlad, 1984; Marzano et al., 1988). These three groups of factors were the basis for our survey content and methods in this part of the study.

Research shows that teachers who lack confidence in teaching science cannot teach science meaningfully. This is an affective variable the study sought to measure. Novice teachers, in particular, will often resort to "safe," explicit teaching strategies (Cunningham, 1995) when uncertain about the content. Further, teachers' beliefs, values, and biases about how to teach science significantly affect how they view themselves as teachers. Once established, these points of view are difficult to change even when inaccuracies and misinformation are pointed out (Goodman, 1988; Nespor, 1987; Thomas, Pedersen, & Finson, 2000), Evidence suggests that even tremendous investments in instructional change, curriculum materials and related equipment have not significantly changed the teaching habits of most teachers (Abell, 1989; Barnes & Barnes, 1989; Otto, 1997) , a testament to the power of stereotypic perceptions to influence how teachers understand the nature of science, and how they approach teaching the subject (Thomas, 2000).

For the current research project, this raises particularly significant questions. What are the implications of these affective variables in teaching science? Could there be a tendency to approach scientific experimentation with a "safe" but ultimately naive inductivist attitude? What if discovery or learning is void of social negotiation?

Is there a practical threat that science in the classroom could become an inauthentic representation of the work of the real scientific community? Could it even occur that a failure of confidence on the part of the teacher could lead to an inaccurate portrayal of scientific processes and concepts, or to teaching science as a series of absolute truths beyond reproach (Cunningham, 1995)?

The Waldorf pedagogy would argue that questions like this are really red herrings, because school science is not about replicating real science, but about developing capacities. On the other hand, extensive research suggests that "an ordinary degree of understanding is routinely missing in many, perhaps most students" (Gardner, 1991). In Harlen's classic and still highly referenced book *Taking the Plunge* (Harlen, 1985) it is evident how prevalent misconceptions in science are, often exacerbated by teachers own misconceptions. AAAS 2061 Benchmarks (American Association for the Advancement of Science, 1993) also examines the prevalence of misconceptions and outlines a rigorous process to change this, although teacher and student misunderstandings continue to abound (Stigler & Hiebert, 1999; Wiggins & McTighe, 1998).

Leaving aside for the moment the merits of one point of view or the other in this discussion, it appears from the research that attitude is as important to developing capacity as it is to acquiring knowledge of specific science content. Haladyna, Olsen, and Shaughnessy (1982) make a strong argument that student attitudes toward science are correlated to perceptions of self and the ability to learn. And studies continue to indicate that student attitudes toward science remain low and get lower the longer students are in school (Hofstein, Maoz, & Rishpon, 1990; Yager & Yager, 1985; Yager & Penick, 1986). Perhaps, as some Waldorf and attitude researchers argue, measures of success are still too concerned with "mastery of science concepts" (Hofstein, Scherz, & Yager, 1986). Still, considerable amounts of research (Oliver & Simpson, 1988; Shrigley, 1990) link attitude with achievement. Schibeci and Riley (1986) found substantial probability that attitude and achievement are highly correlated, and their data supported the position that students' perceptions of instruction influence these attitudes. They concluded that such teacher variables as enthusiasm, enjoyment, and motivation can influence student achievement. It seems, therefore, that whether the instructional focus is on content, capacity, or some mixture of the two, affective factors may be potentially significant.

Educational researchers are clearly no strangers to affective factors, and there is a seeming overabundance of methods from which this study might have chosen. We reviewed existing research on attitudes toward instructional variables (Allen, Klingsportn, & Christensen, 1980; Durkee, 1974; Sparks & McCallon, 1974); in specialized programs (Yager, 1982); influenced by classroom climate (Haukoos & Penick, 1983); and toward science and scientists (Fraser, 1978). These studies and their results produced ambiguous findings, and when those studies involved affective factors in science education serious issues of confidence and validity arose. Munby (Munby, 1983) examined the use of the Scientific Attitude Inventory (SAI) in thirty studies conducted over a ten year period and concluded " ... not only is the field of measuring attitudes replete with instruments, but that these instruments are used in a rather cavalier fashion, without heed to their reliability and validity" (p. 161).

The Revised Science Attitude Scale (Thompson and Shrigley, 1986) has addressed many of these limitations in reliability and validity, and served as a model for the Waldorf survey protocols that were developed for this research. The Science Attitude Scale was supplemented with more conceptual-based questions since it seems that a shortcoming in much of the science survey literature is that it often stresses affective components at the expense of conceptual development, i.e., the cognitive domain of metacognition. Cognition deals with conceptual learning, with an underlying premise that the *concepts* being learned are accurate.

While the Waldorf survey and interview protocols were not designed to specifically test teacher conceptual understandings (or misunderstandings), they do include questions to ascertain Waldorf teachers' perceptions of the role of conceptual understanding and development in science education. The protocols which have been developed have served the purpose of gathering data to elucidate the metacognitive factors presented herein.

In the Classroom

This component of the study analyzed videotaped observations of science lessons according to well-established criteria for effective science instruction. This component also seeks to answer the fourth research question, "How do Waldorf students' scientific reasoning and problem solving skills compare to those of their counterparts in mainstream educational settings?" We avoided assessing specific conceptual knowledge of students as it could be argued that a fair comparison could only be made under controlled circumstances in which all groups received instruction on the same content. Instead, we selected the TIMSS Magnet task and nonverbal reasoning and problem-solving tasks because they assess non-content specific skills and strategies. In all cases, well established databases exist for comparison purposes.

Relevant Literature. Whether Waldorf students perceive and reason about the world differently is an intriguing question, and one way to approach it is through the domain of *logical reasoning,* traditionally viewed as a central element in intelligence (Sternberg, 1997). The kinds of logical reasoning tests to administer becomes a central concern, however, as exemplified in Lesser, Fisher and Clark (Lesser, Fifer, & Clark, 1965) who found that when a cognitive performance task requires verbal understanding (instruction), manipulation, or elaboration, logical reasoning is subject to four factors: (1) how familiar its content is to the audience; (2) the age of the person; (3) the format used to express it; and (4) the plausibility of its assertions in terms of one's world knowledge and cultural norms. In short, the ways of stating logical reasoning tasks is pivotal to performance.

For the above reasons, non-verbal as well as verbal tasks were administered to 4^{th}, 6^{th} and 8^{th} grade students in this study. The non-verbal tasks are based on the Test of Non-Verbal Intelligence (TONI) (Brown, Sherbenou, & Dollar, 1982), which is considered a language-free measurement of cognitive ability. The non-verbal items in this task require subjects to solve problems by identifying relations among abstract figures. Each item consists of (a) a stimulus set of figures, and (b) a set of response choices. The stimulus set presents a set of figures in which one or more of the figures is missing. The subjects complete the set by selecting the correct figure from the response choices (either four or six response alternatives). The symbols depicted in the non-verbal logic test include one or more of the characteristics of shape, position, direction or rotation, contiguity, shading, size or length, movement and pattern within the figures.

The verbal logical reasoning task used in this study was an adapted version of the Cornell Class-Reasoning Test (CCRT), Form X, (Ennis, 1985). The CCRT test consists of multiple-choice items, with 30 minutes allocated for the test administration. The tasks focus on "deductive logic," which has been considered fundamental and pervasive in human thinking. Deduction implies that thinking involves the combination of existing information by following specific mental operations, as in addition or subtraction (Mayer, 1992). In deductive logic, the propositions or rules are given and the thinker uses the given information to derive a conclusion that can be proven correct. Mathematical proofs, for example, are deductive. Although deductive operations could be seen as tasks rather than theories of thinking (Mayer, 1991), they have an implied view of human thinking. For example, Mayer (1991) focused on the perspective suggested by work in deduction that thinking involves combining information by using a set of psychological and mathematical operations. Mayer interprets thinking as the processing of premises by using specific operators--similar but not identical to formal logical operators (Mayer 1991).

The main focus of the deductive reasoning approach is the syllogism, which consists of two premises and a conclusion. There are three types of syllogisms that are often mentioned in textbooks on logical reasoning: (a)*class syllogisms*, such as "all A are B; all B are C; therefore all A are C"; (b)*linear syllogisms*, such as "A is greater than B; B is greater than C; therefore A is greater than C"; and (c) *conditional syllogisms*, such as "if *p* then *q*; *p* is true; therefore *q i*s true." The present study focuses on the first type of syllogism, the *class syllogism*, due to its focus on part-whole relations of class-membership and inclusion (Piaget, 1969). According to Waldorf pedagogy, an underlying principle of teaching is to proceed from the whole to the parts (Steiner, 1966). It will therefore be intriguing to investigate where or not there is evidence of logical patterns emerging from this approach.

The nature of the part-whole relation has been a source of controversy and confusion in terms of what role it plays in logical thinking (Lyons, 1977; Winston, Chaffiiin, & Herrmann, 1987). Although most researchers agree that the part-whole relation is of prime importance in human cognitive processing, some senses of the relation seem to appear earlier than others; that is, some are more primitive developmentally than others (Iris, Litowitz, & Evens, 1988). A majority of studies in the field of the development of logical reasoning have been concerned with the question of the relative extent to which a child focuses on either the part or the whole in perception. Werner (Werner, 1957)claimed that perception proceeds from a diffuse organization characterized primarily by "qualities-of-the-whole" into an organization in which the essential feature is a decisiveness of parts. Early studies done by Hemmendinger (Hemmendinger, 1953) reported data attesting to the tendency of American children to focus predominantly on the whole configuration as opposed to the individual parts in visual perception. Heiss (Heiss, 1930) reported on the greater difficulty the younger groups in his study had in finding small shapes embedded in a large configuration. Based on this finding, Lowe (Lowe, 1973) hypothesized that this whole-oriented perception has a possible impact on the perception of the parts and that younger children, when their attention is directed to the parts of a larger configuration, perceive the parts in terms of qualities of the total configuration. Their perceptual functioning results in a specific, predictable dissimulation of the parts--i.e., the parts shift in appearance to look like the larger wholes.

Science problem-solving skills, the third area of focus in our assessment of Waldorf students, was derived from the Third International Math and Science Study magnet task (Harmon et al., 1997). TIMSS is the largest and most comprehensive international study of school math and science ever conducted, providing a rich resource of validated science assessments and data bases. Conducted in 1995, TIMSS compared 42 countries at three grade levels in multiple dimensions. The magnet task represents just one of 13 practical tasks to assess student content knowledge and problem-solving abilities. This is important to keep in mind when the Waldorf student results are compared to TIMSS. Obviously a more comprehensive study is needed to do an adequate comparison.

On the other hand, TIMSS findings have revealed many rather intriguing considerations of significance to this study. For example, there is strong evidence to suggest an inverse relationship between content and achievement; i.e., those who performed highest were not those who were taught the most content, had the most homework or the most instructional time allotted to the subject. Simply put, the highest performing countries are not the countries who taught the most (in content or time). These findings bode well for Waldorf which argues against the “more is better” approach to education, where homework in the early years is frowned upon and textbooks are generally not used. TIMSS results also validate the National Assessment of Educational Progress (NAEP) data that no gains have been made in higher-order thinking or scientific performance for the past quarter century(U.S. Department of Education, 2003). From TIMSS survey data U.S. teachers’ focus 60% of their teaching on skills and 20% on thinking; 95% on practice procedures, less than 5% on concept application and less than 2% on inventing/thinking. By comparison the Japanese teachers’ focus 25% on skills and 75% on thinking,; 40% on practice, 10% on concept application and over 45% on inventing/thinking (Wiggins, 2001). The significance of these statistics is clear when performance scores of the 2 countries are compared. Japan (and almost all other countries) outperformed the United States in understanding and performance, leading to the conclusion that “…the felt obligation to cover content … is not an effective strategy” (Wiggins, 2001). Exactly where Waldorf students compare will be impossible to say based on the data from a single TIMSS task, but as the data will show below, on that single task they have performed above the U.S. and in some cases close to Japanese students. This means, that further investigation – perhaps a larger scale comparison – would be well justified.

The final component of *In the Classroom* focuses on teaching behaviors according to generally accepted principles of inquiry instruction. Teaching science through inquiry has a long history – legitimized by Dewey and revisited in extensive literature since that time (Dewey, 1938; Lederman & Druger, 1985; Roth & Roychoudhury, 1993). The National Science Education Standards have established Inquiry as one of its 8 categories of science content standards, and most methods of science education include inquiry as a central theme. Exactly what inquiry is and how it can be successfully implemented in classroom practice has not reached consensus, however, even though certain models have emerged. The Constructivist Learning Model (CLM) (Yager, 1991) seems among the most promising, having stood the test of time for more than ten years, refined over those years to be more teacher/context-friendly (Peters & Gega, 2002). Illustrated in table 15 the premise is that CLM is an ongoing process in which students are "invited" into the process through some kind of intriguing opening, leading to "exploration" that engages students in the scientific process. These steps then progress to "proposing explanations and solution" and "taking action", though not in any neat, linear fashion. The point is that some aspect of all four categories of the CLM occurs in the ideal inquiry lesson, and a table such as table 15 can help distinguish to what extent the various components occur.

Table 1 on the following page summarizes the data, procedures, and analysis of these three studies. Elaboration is provided in the chapters that follow.

Table 1. Data Sources, Procedures and Analysis

Study	Data	Procedures	Analysis
Curriculum & Assessment	1. Waldorf Science Curriculum 2. Curriculum Rating Tool 3. Waldorf Science Kits 4. Science Kit Evaluation Questions.	• Curriculum reviewed by external evaluators using *Science Curriculum Rating Sheets"* A 1 to 5 Likert scale + Narrative Feedback. • Kits field Tested by 25 beginning teachers. Narrative responses to 5 criteria.	• Qualitative: Content analysis of narrative and informal feedback. Coded & categorized using Constant Comparative Analysis (CCA). • Quantitative: Central Tendency, Variability, & Frequency Distribution
Surveys and Interviews	1. Focus Group Interview Protocol 2. Waldorf school delegates questionnaire 3. Interview Protocol for Teaching Waldorf Science Lessons 4. Open-ended Questions: Science Teaching in Waldorf Schools 5. Waldorf Science Education Survey	• Interviews conducted in teacher's school setting, taped and transcribed. Representatives from all regions and Hawaii were interviewed. • Survey administered to 50 Waldorf School across North America; 240 respondents.	• Qualitative: Constant Comparative Analysis (CCA) of all verbal and written narratives • Quantitative: Central Tendency, Variability, Frequency Distribution, Correlation Coefficient, Regression Analysis & Chi-Square.
In the Classroom	1. Non-verbal Logical Reasoning Task 2. Verbal Logical Reasoning Tasks 3. TIMSS Magnet Task 4. Videotapes – Waldorf science lessons	• Administered tasks to 4^{th}, 6^{th} & 8^{th} Grade Waldorf Students in representative schools on East and West Coast plus Hawaii. Videotaped complete lessons from representative teachers in different parts of the country. Coded and analyzed lessons according to Inquiry Analysis criteria.	• Qualitative: Constant Comparative Analysis (CCA) of student narrative data. Videotaped lessons coded according to, Inquiry Analysis codes, using 1 minute sweeps. • Quantitative: Central Tendency, Variability, Frequency Distribution, variance, *t*-test, and Chi-square.

CHAPTER 3

Curriculum & Assessment

Data

1. Waldorf Science Curriculum. We reviewed *The Curriculum of the First Waldorf School* (Hutchins, 1966,1984), documenting Rudolf Steiner's original conception of the Waldorf curriculum; and Waldorf science education literature and materials gathered from a variety of Waldorf schools. From these materials, we drafted the Waldorf Science Curriculum by grade level under five categories: (1) curriculum of the first Waldorf School, (2) overview, (3) objectives, (4) topics, and (5) strategies. Available electronically by emailing djelinek@csus.edu.

2. Curriculum Rating Tool. The tool identifies 27 criteria under 3 domains (pedagogical appropriateness, science content, and presentation & format), rated on a Likert scale of 1 to 5. Prompts for narrative feedback are also provided. Seven separate grade-level curriculum ratings were conducted (grades 1-3, 4-5, 6, 7, 8, 9-12, and 1-12 overall).

3. Waldorf Science Kits. We obtained *Waldorf Science Kits*, materials developed by Waldorf science teachers. The kits contain materials used in the classroom to carry out hands-on or demonstration activities in electricity, magnetism, acoustics, heat, optics, hydraulics, botany, and chemistry. Minimal written instructions are provided, though several of the kits complement activities discussed in *Sensible Physics Teaching* (D'Aleo & Edelglass, 1999).

4. Science Kits Field Evaluation Questions:

- Are the concepts realistic? Do the activities address the unit's concepts/sub concepts?
- Can students relate to the concepts?
- Do the materials work as they are suppose to?
- Are these realistic materials?
- What else is needed?

Procedures

The Waldorf Science Curriculum and supplemental pages excerpted from several Waldorf science education publications were provided to a group of external reviewers, including public school science educators, university science faculty, university science teacher education faculty, and science education specialists representing various disciplines (environmental, geology, biology, chemistry, and physics). Reviewers were asked to independently assess the curriculum using rating sheets adapted from "Criteria for Selecting Inquiry-based Science Curriculum Materials" (The National Academy of Sciences, 1997,2000).

The Waldorf science kits were provided to 25 first year public school elementary teachers to try out with their respective classes. We wanted to see how new teachers with no prior Waldorf experience would react to the kits in the classroom. The teachers underwent 18 workshop hours in K-8 science methodology related to concepts similar to those identified in the kits. These workshops, however, did <u>not</u> include direct instruction or reference to the Waldorf Science Kits. Thereafter, the teachers worked with the kits over a minimum of 2 class sessions, then provided a written evaluation based on the 5 questions identified under *data*.

Analysis

Three tests of the curriculum statistical data were conducted: (a) Central Tendency; (b) Variability; and (c) Frequency Distribution. Constant Comparative Analysis was applied, and the resulting representative statements are shown in bullet points below.

Written responses to the science kits were also evaluated using CCA. Representative responses for each of the 5 questions were identified and recorded in a grid. Isolated responses that occurred only once and therefore could not be depicted by representative statements were recorded in the grid to assure complete coverage of the perspectives.

Findings

Table 2. Descriptive Statistics for Pedagogical Appropriateness

Review Questions*	Minimum	Maximum	Mean	SD
1. Do the materials focus on concrete experience with science phenomena?	.70	.95	.8357	.08
2. Do the materials enable children to investigate important science concepts in depth over an extended period of time?	.75	.90	.8429	.06
3. Do the curriculum materials contribute to the development of scientific reasoning and problem-solving skills?	.55	.90	.7357	.1249
4. Do the materials stimulate students' interest and relate science learning to daily life?	.80	1.00	.8929	.08
5. Do the materials build conceptual understanding over several lessons trough a logical sequence of related activities?	.70	.90	.8086	.07
6. Does the instructional sequence include opportunities to assess children's prior knowledge and experience?	.80	.90	.8500	.03
7. Does the material focus on student inquiry and engage students in the processes of science?	.60	.95	.7786	.1286
8. Does the material provide opportunities for students to gather and defend their own evidence and express their results in a variety of ways?	.70	.85	.7857	.05
9. Does the material include a balance of student-directed and teacher-facilitated activities as well as discussions?	.60	.90	.7357	.09
10. Does the material incorporate effective strategies for the teacher and/or students to use in assessing student learning?	.55	.70	.6300	.05
11. Do students have opportunities to work collaboratively and alone?	.65	.95	.8000	.09

* Adapted from "Criteria for Selecting Inquiry-based Science Curriculum Materials" (The National Academy of Sciences, 1997,2000)

Figure 2. Comparisons of Mean Percentages for Pedagogical Appropriateness

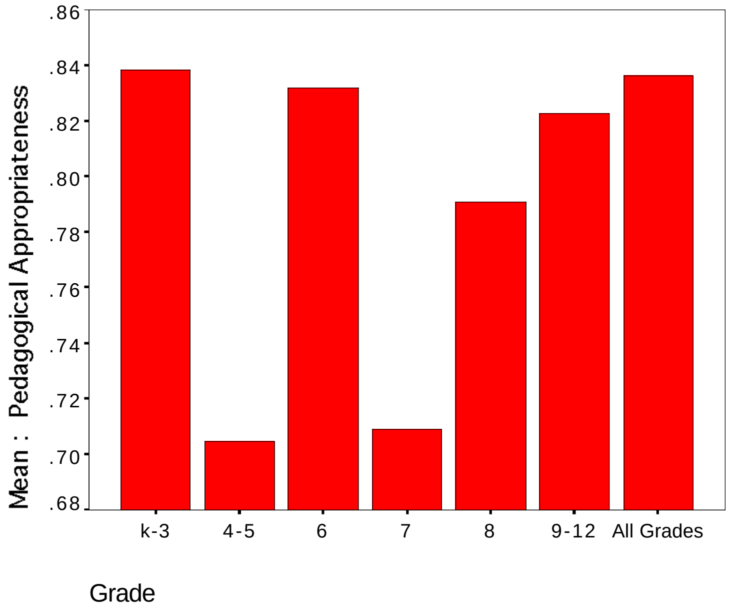


Table 3. Descriptive Statistics for Science Content

Review Questions*	Minimum	Maximum	Mean	SD
1. Is the science content current and accurately represented?	.60	.80	.7071	.007
2. Does the content emphasize scientific inquiry? "Evidence of scientific inquiry includes opportunities for students to ask questions, plan and conduct investigations, use appropriate tools and techniques to gather data, think critically and logically to develop explanations based on what they have observed, construct and analyze alternative explanations, and communicate scientific arguments." (Science for All Children, National Academy of Science,1997,2000)	.55	.85	.7214	.1113
3. Is the content of the science program consistent with the National Science Education Standards? "The Standards specify the knowledge and skills children at various levels should acquire in physical science, life science, and earth and space science. They also include information about what children should know in the areas of science and technology and of the history and nature of science [and] about how students can learn to use scientific knowledge to make informed decisions."	.60	.80	.7071	.08
4. Does the background material for teachers address the science content that is taught, as well as common misconceptions?	.55	.70	.6300	.05
5. Is the treatment of content appropriate for the grade level?	.80	1.00	.9043	.07
6. Is the content free of bias?	.75	.85	.8143	.04
7. Is scientific vocabulary used to facilitate understanding rather than as an end in itself?	.70	.80	.7643	.04
8. Is science represented as an enterprise connected to society?	.70	.95	.8714	.09

* Adapted from "Criteria for Selecting Inquiry-based Science Curriculum Materials" (The National Academy of Sciences, 1997,2000)

Figure 3. Comparisons of Mean Percentages for Science Content

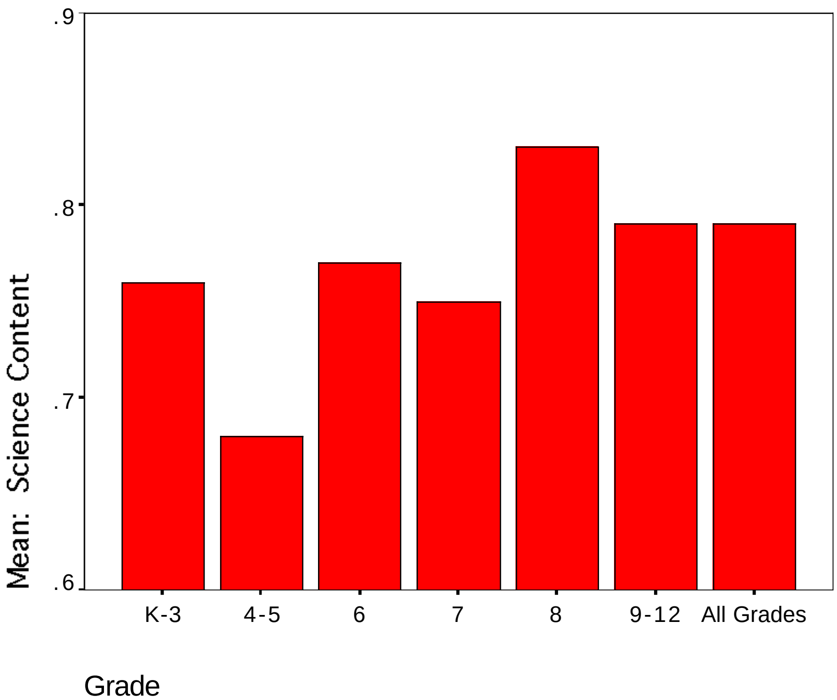


Table 4. Descriptive Statistics for Presentation & Format

Review Questions*	Minimum	Maximum	Mean	SD
1. Are the print and/or other instructional materials for students clearly communicated, developmentally appropriate and compelling in content?	.60	.70	.6571	.005
2. Are the directions for implementing activities clear?	.27	.75	.5200	.1560
3. Are suggestions for instructional delivery in the teacher's guide adequate?	.33	.75	.5657	.1382
4. Are the materials free of ethic, cultural, racial, economic, age, and gender bias?	.70	.93	.8186	.008
5. Are appropriate strategies provided to meet the special needs of diverse populations?	.45	.80	.5929	.1169
6. Are lists for materials for each activity provided, as well as a complete set of materials and information about reasonably priced replacement materials?	.20	.70	.4614	.1826
7. Are safety precautions included where needed?	.27	.65	.4500	.1217
8. Are instructions for using laboratory equipment and materials clear and adequate?	.20	.60	.4043	.1667

* Adapted from "Criteria for Selecting Inquiry-based Science Curriculum Materials" (The National Academy of Sciences, 1997,2000)

Figure 4. Comparisons of Mean Percentages for Presentation and Format

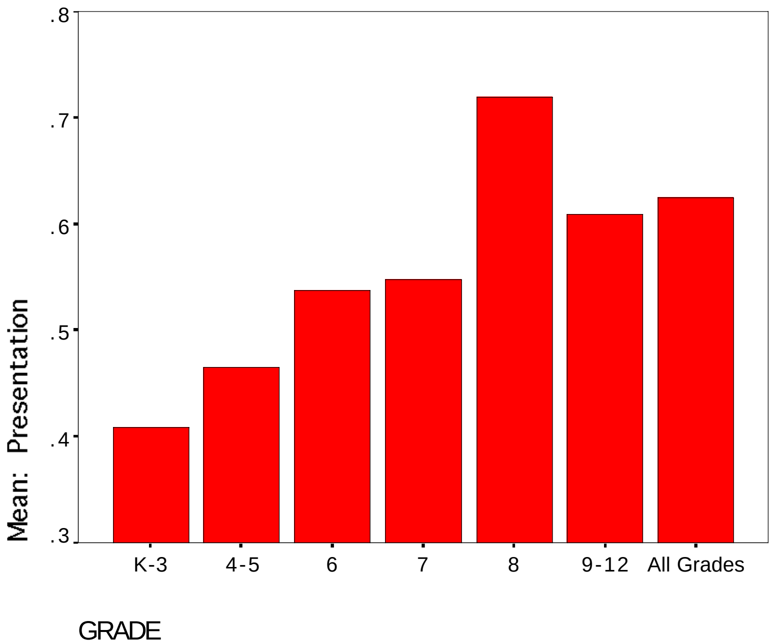


Table 5. Representative Narrative Evaluations on Pedagogical Appropriateness

Pedagogical Appropriateness	
Grades 1 to 3	
Public School Teacher	• Each year the curriculum overlaps and goes a little more in depth in the provided (k-3) topics. This provides adequate foundation for building upon prior knowledge and making new connections • The nature walk will be a great means by which students can collect evidence and express their results. There are several opportunities provide by which students can collect evidence, but there aren't too many strategies provided by which students can defend their evidence and display results. How will they do this?
University Science Educator	• It is difficult to determine the depth of experience in the k,1,2 grades • Grade 3 has high engagement- farm, home building…
Grades 4 to 5	
Environmentalist	• I support the educational philosophy of the Waldorf science curriculum. I question the generalized delivery of this science curriculum. How exactly will Drama, music and art be incorporated in the lessons?
Public School Teacher	• The curriculum easily lends itself to the opportunity for the students to work collaboratively. • The opportunity for effective problem solving is there, but it would be good to include some examples of individual lessons that portray the teaching of problem solving skills. • How will the teacher know if the students got it? How would one directly assess what the students learned? What are the assessment criteria?
University Science Educator	• Can't tell if any long term projects exist. • It appears to be simple comparing identifying • It would be nice to have the questions or the experiment identified that support injury.
Grade 6	
Biologist	• Few opportunities for group or collaborative work are specified in the materials- the emphasis is given to individual experience and learning
University Science Educator	• There is inquiry, however there is evidence the teacher guides to the point of 'telling the students what they saw in a demonstration'. This is only okay if it is only the steps and not the phenomena.
Grade 7	
Public School	• The students apply what they have learned in science in grades k-6 to the human experience once

Pedagogical Appropriateness	
Teacher	again. It is here that the curriculum comes full circle
University Science Educator	• "God.. in image" not true for all religions.. should this be in science? Is it testable? What if science roved God exists? • Page 10 "food…warmth".. This is relative, is all food developed with warmth? Arctic? • No mention of bacteria in lower intestine and significance. • Page 15 bones are the most "lifeless" what does that mean? They are alive… this implies there are degrees of life in your body? Philosophy or science?
Grade 8	
Public School Teacher	• Each year the curriculum provides a smooth transition and over-lapping of concepts • What is the % of student directed vs. teacher directed instruction?
Grades 9-12	
Biologist	• The emphasis on experimentation, demonstration and observation is a strength of the curriculum. A good deal of thought has clearly been given to developmental appropriateness as well.
Public School Teacher	• The curriculum provided teaches children to think outside the box and use what they have learned in science to effectively problem solve.
University Science Educator	• Concepts/content appear to be strong, more developed. Nice. • Strong: farm experience. • Interesting 11 grade "teacher describes" technology. Why not the students. This is a question of ownership of learning, so nicely provided in 9 and 10th grades.
Overall (Grades 1 to 12)	
Biologist	• The Waldorf emphasis on close observation, experiments and demonstrations, and in-depth exploration of concepts are strengths. The developmental sequence of the curriculum is thoughtful and thorough.
Public School Teacher	• Each year provides an overlap of concepts and a building of prior knowledge/new connections • Over-all, the curriculum is pedagogically sound, enriching and engaging. Each year provides a snap shot of the curriculum provided for the particular grade level.
University Science Educator	• Overall impressive pedagogically. My feeling is there are grade level weaknesses. I would like to see inquiry more explicit and open to students original design. Also a point that may conflict with the Waldorf philosophy, my apologies, but more explicit acknowledgment of the dichotomy between science and philosophy .

Table 6. Representative Narrative Evaluations on Science Content

Science Content	
Grades 1 to 3	
Biologist	• Although representation of animals in anthropomorphic ways may be developmentally appropriate, I don't think it can be considered scientifically accurate. • Emphasis in these grades is on life science; less attention is given to NSE standards for earth and space science, science and technology
Public School Teacher	• A thoughtful integration of humans, animals, plants, and nature is included in the k-3 curriculum. This provides a very cohesive approach to the curriculum.
University Science Educator	• Inquiry is more evident in grade 3 than k-2 • Little evidence the standards are overt to the teacher- no evidence of student awareness. • "free from bias"—this score is a positive intention score, in their curriculum is bias in the philosophy of Waldorf schools. Therefore it includes practices and content that are not necessarily experimental science but do expand into the qualitative and social science.
Grades 4 to 5	
Biologist	• In these grades in particular the content is highly colored by the philosophy of Waldorf. The presentation of animals as somehow representative of parts of aspects of the human being concerns me. While I would need to study Waldorf pedagogy in greater depth t reach firm conclusion, it is clearly a very specific take on the world, and is therefore likely to be colored by that interpretation of life. I have reservations about the scientific accuracy of some of the content.
Public School Teacher	• In 4-5th grade there is a shift from holistic to objective in terms of curriculum focus. At this time, the students may be presented with open ended question about animal and plant kingdoms and may be

Science Content	
	asked to research on their own or in groups. The curriculum provides an excellent opportunity to guide the children through discovery of concepts. The teacher should utilize scaffolding to guide the learning of the children.
University Science Educator	• In the supplemental materials the science seems sketchy, and questionable. My question is whether the anthropomorphizing the sun, etc, is scientifically sound. It may be good philosophy but it is not science.
Grade 6	
University Science Educator	• Is the inquiry guided or open? It seems to be guided. Do students get to consider their knowledge or understanding? • The content is strong, but I am not convinced it is aligned to all standards for Grade 6.
Grade 7	
Biologist	• In the NSE standards students begin to study cells in middle school, while Waldorf curriculum does not address cells until 11th grade (though not much time is spent on cells in NSES until high school) • The presentation of human physiology is colored by Waldorf philosophy on the threefold human being and soul-spirit.
University Science Educator	• Some of the writing has explanations that may support preconceptions or student misconceptions. For instance, bone is the "least living".
Grade 8	
Public School Teacher	• The curriculum provides students with the opportunity to do individual research investigations which stimulate inquiry. For example, the students might test the bio-chemical constituents in some common snack foods by testing them for fat, C.H.O., mineral content.
Grades 9-12	
Biologist	• I don't see genetics being treated anywhere in the Waldorf curriculum . (Did I overlook it or does Waldorf?) Ditto for evolution. • Also, there is little evidence of specific treatment of modern environmental issues, such as population dynamics, pollution, resource allocation, etc. • These omissions are why I have marked questions 41 & 43 as merely "Somewhat" in other areas, such as chemistry, it is very complete.
Environmentalist	• How will the students be engaged in the learning process? • Where to the teachers find out about how organs relate to the life of the soul and sprit? You won't find that in y our common biological text.
Public School Teacher	• More student centered lab activities. • In grade 12, the curriculum provided makes connections between modern developments in economics and labor.
University Science Educator	• Strong connection to society
Overall (Grades 1 to 12)	
Biologist	• My own views/understanding of science concepts aligns with Waldorf in some respects and differs sharply in others. I am a bit concerned that the curriculum presents Waldorf philosophy as THE answer, without presenting other views of science- then again- mainstream Western theories of science could be faulted for the same thing. But, the NSES do emphasize the skeptical nature of science and scientific dialogue, and I'd like to see more of that here.
Environmentalist	• Different teachers will teach this Waldorf science curriculum in vastly varying degrees depending on their science background. All teachers need a curriculum that is complete with resource materials, lesson plans, activities and materials. They should be allowed to adapt these teaching materials but should have to research and create them as they teach.
Public School Teacher	• Expose students to more technology during early years (k-3). This can be achieved via a computer program that allows the children to interact with science concepts. Show videos on how things work. Focus not only upon what, but also, the how of the things • Make sure students know, understand and apply science concepts in real world situations make connections between the phenomena.
University Science Educator	• Great connection to society • Good alignment to the NSES • I struggled with #49, the challenge of having religion/philosophy defined the science content as well as the anthropomorphism present.

Table 7. Representative Narrative Evaluations on Presentation and Format

Presentation and Format	
Grades 1 to 3	
Biologist	• Question 12 is difficult to assess from the materials provided, but I do notice that all of the quotations and references included appear to be from white, male sources, which, if not balanced elsewhere in the materials, may be indicative of bias. • I have not seen any reference to differentiated instruction or diverse populations.
Environmentalist	• Teacher training and resource materials are probably available, but I haven't seen these in this curriculum, • The Waldorf science curriculum cold be made more complete if activities accompanied the concepts of nature walks, sensory observations, etc.
Public School Teacher	• Include some ideas for nature activities. What will be the focus of the nature walks… living vs. non-living, inventory; signs of pollution, etc. What types of activities will be included in the farming project. • Lists of materials need to be included as well as safety precautions for materials used. There were not any instructions for using lab equipment. A lab safety lesson should be taught before the students use any of the lab equipment. This can include a lab safety and procedures test.
University Science Educator	• There is little evidence provided for the specificity identified in this category.
Grades 4 to 5	
Environmentalist	• When detailed lesson plans are developed to address the learning objectives of the students the Waldorf science curriculum well become more effective in teaching science and engaging students in the scientific process.
Public School Teacher	• Will students do any dissections on plants or animals? Also teach a lesson on lab safety. Make up safety contract for students to sign and take a lab safety test.
Grade 6	
Biologist	• Continuous use of "man" in the universal sense- though there is a visible effort to avoid gender-specific terms • I saw no specific references to differentiating instruction or meeting /addressing the needs of diverse student populations.
Public School Teacher	• There aren't any specific directions for implementing activities. For example, if students are going to conduct experiments or participate in demonstrations, what types of experiments will they be and what will be the directions for carrying them out. • What safety precautions will the teacher take in preparing the students for an intense yet educational and safe lab experience? This becomes increasingly more important as the students continue in their research and participation in more potentially hazardous lab activities. A lab safety lesson/contract/test is a must.
Grade 7	
Biologist	• I don't see references to diverse populations, though I get the impression that Waldorf is very focused on individual growth and experience.
Grade 8	
Public School Teacher	• For strategies/methods of teaching grade 8 part B refers the reader to part c of the curriculum. There is a good and quite informative section on methods of teaching physics. • The implications of safety are mentioned in part C, but it is still important to dedicate an entire lesson each year to lab safety. • There needs to be a lesson or debriefing before each lab activity on how to use the equipment provided.
University Science Educator	• Strong unit
Grades 9-12	
Environmentalist	• Grade 12- "each animal appears as an elaborate organ or limb of the human being". This statement is wrong, a misinterpretation of biological science. • Waldorf science curriculum makes statements I don't agree with such as "At the same time all realms of nature should be seen together in a united whole, with the study of man as a central theme running through the lessons". We are a part of the whole I agree but we shouldn't be the central theme. That idea gives humanity more importance than the rest of nature and that is a mistake in my opinion.
Overall (Grades 1 to 12)	
Environmentalist	• There are plenty of science education materials that could be adapted to the Waldorf Science curriculum This would alleviate my complaint of needing exact content requirements and style of presentation and format.
Public School Teacher	• For each strategy/ activity utilized, there needs to be a set of instructions. To assess whether or not the instructions are adequate, even a person without a science background should be able to understand the instructions if they are clearly written. • Attention must be taken to make sure thee lessons are sheltered for ELL students, and accessible for the special needs population.,
University Science Educator	• I saw, consistently, little evidence of addressing all students, including special needs.

CHAPTER 4

Surveys and Interviews

Data.

1. Focus Group Interview Protocol
2. Waldorf school delegates questionnaire
3. *Interview Protocol for Teaching Waldorf Science Lessons*
4. Open-ended Questions: Science Teaching in Waldorf Schools
5. Waldorf Science Education Survey

Procedures

Eight focus group interviews were conducted to gain a sense of science education perspectives within the Waldorf community. One group consisted of Waldorf Association "Pedagogical Section" representatives; two groups consisted of teachers attending the West Coast Waldorf Teachers' Conference (representing over 20 Waldorf schools); one group represented Waldorf teacher training representatives; one group represented all grades of a California and one a Massachusetts Waldorf school faculty; and two groups represented faculty representatives from 2 California public Waldorf methods schools. Some interview data were taped and transcribed; otherwise notes were taken. All data were entered into Folio Views for Constant Comparative Analysis (CCA) qualitative interpretation.

The Waldorf school delegates questionnaire was administered to 20 Waldorf Delegates at their annual meeting in January, 2001. Written responses to 3 questions were entered into a matrix.

Data from focus group and the delegates questionnaire were used to help formulate two interview protocols for interviewing individual teachers and reputed experts on Waldorf education. Interviews were taped and transcribed, then entered into Folio Views for CCA analysis.

The Waldorf Science Education Survey consisted of 13 questions and was administered to over 200 Waldorf teachers from 40 schools in the United States. Participants responded to questions on a 5 point Likert scale from "strongly agree" to "strongly disagree". Narrative responses were also provided. Numerical data were entered into SPSS for statistical analysis and narrative data were entered into Folio Views for CCA qualitative analysis.

Analysis

1. CCA analysis of Waldorf Delegate narrative responses was conducted to determine common themes. Narrative responses were also entered into a matrix to provide the participants' perspectives in their own words.

2 . CCA analysis of Focus Group and Individual interview data generated 5 predominant categories of responses: (a) Lesson Planning, Preparation & Implementation; (b) Science Education in the Waldorf Context; (c) What do

Students Learn and How do you Know?; (d) Waldorf Science Education in the Mainstream Context; and (e) Waldorf Teacher Training.

3. The 13 survey questions were grouped under 4 categories: (a) Knowing What to Teach; (b) What is Important to Teach; (c) Confidence in Teaching Science; and (d) Assessment. Six statistical tests were conducted: (a) Central Tendency; (b) Variability, (c) Frequency Distribution, (d) Correlation Coefficient, (e) Regression Analysis, and (f) Chi-Square.

Narrative responses were coded, recoded and categorized using Constant Comparative Analysis to generate "memos"; i.e., characterizations of representative statements for the 4 categories of questions. These representative responses are provided in bullet points for each of the 4 categories.

Findings

Figure 5 to Figure 8 summarize the survey numbers in graphical form. A complete electronic data set by question number and years experience is available by emailing djelinek@csus.edu. Table 8 to Table 11 provides representative narrative responses to the survey questions. Table 12 provides representative responses to interviews, categorized by experience level as follows:

- Student Teacher: Still in training or at pre-professional level
- Beginning Teacher: In the 1st, 2nd or 3rd year of Waldorf teaching
- Master Teacher: In the 4th year of Waldorf teaching or beyond. Third year Waldorf teachers with extensive prior teaching or science background were also included here.
- Expert: Experienced Waldorf teachers recognized nationally in the movement as experts in Waldorf science education. E.g., they conduct classes or workshops in science methods; they have published science education material.

Figure 5. Knowing What to Teach

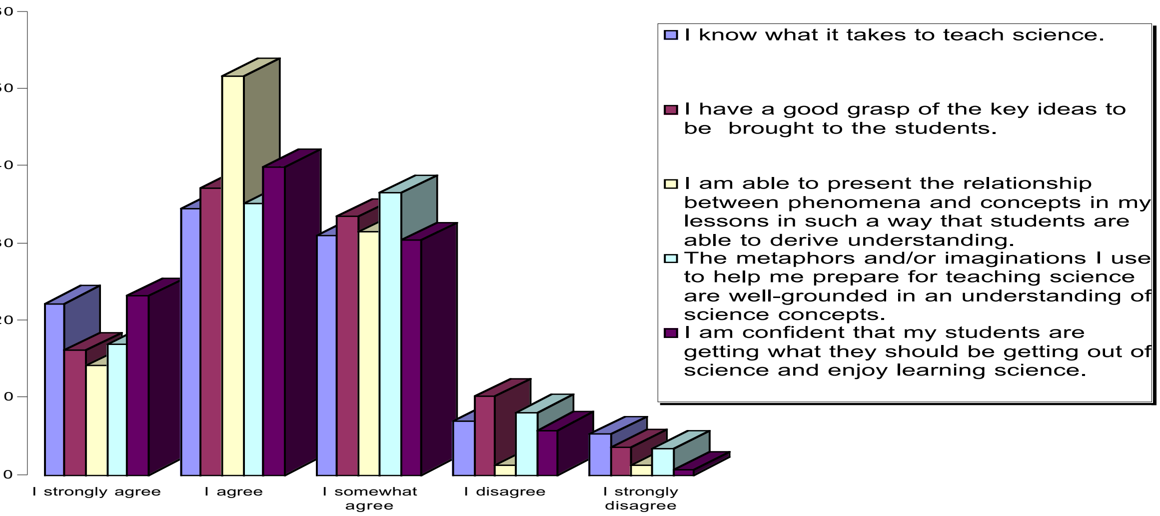


Table 8 Representative Statements on Knowing What to Teach

What teachers say about Knowing what to Teach(by Years of Waldorf Teaching Experience) *(Q 3, 6, 10, 11, 12)*	
0 to 3 Years Experience	• My experience of learning (And enjoying) science is very different from my perception of how science should be taught in Waldorf School. • They must discover the "Cause and effect" on their own and not be told how or why by the teacher. • If I am too well-grounded in my knowledge what I live with and what I bring to the children is not very lively. • I think they are developing a thirst for science. What they "should be getting out of science" I'm not sure. This varies wildly- we lose many students at the 8th grade or younger, they want more challenge in the sciences than we provide.
3 to 5 Years Experience	• I know I can find out by interviewing colleagues and combing books. • Always learning. My background is in the sciences and I feel very strongly that the Waldorf approach to science is extremely valuable to today's children. But I have to undo my own science training to a certain extent. • Not 'til I'm well into planning the block does it seem to come clear.
6 to 10 Years Experience	• From a layman's perspective, as a class teacher I often feel like jack of all trades and do my best to give the basics. • I studied for 8 months to get a handle of 7th grade chemistry the 1st time. I taught it the next year for the class behind me, what fun! It made me think that specialization is the way to go for 7th and 8th grade. • Only when I truly grasp the concept myself. Often I follow the recipe and my understanding is shallow. • Depends on the science topic. I did great in Astronomy and geology, chemistry required tremendous study. • They generally love science block, but I can't say whether or not they are getting what they need.
Beyond 10 Years Experience	• Knowing what it takes does not mean I will be able to do what it takes. • Both in chemistry and earth science there is not a clear curriculum. • Will need to go to school myself to teach grades 6-8 sciences. Needs of upper grades moving into adolescent search for truth.) • Once again, the children must arrive at the concept themselves. • Some say it's their favorite block, others struggle. It could be better with a science specialist, more time, better equipment.

Emergent themes:

- Many of the key ideas to teach are vague-- study, preparation, & consultation are the answer.
- When the teacher has a good grasp of the relationship between phenomena & concepts the results can be exhilarating.
- Most teachers feel a greater conceptual understanding is needed if metaphors/ imaginations are to be used effectively.
- Limitations in facilities, time, equipment, and science specialists means not all students are getting what they should be getting out of science.

Figure 6. What is Important to Teach

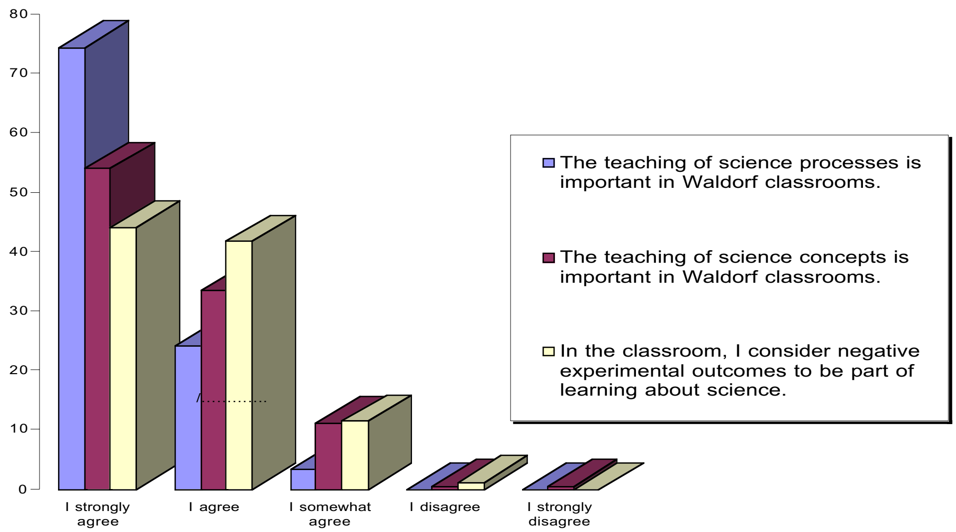


Table 9. Representative Statements of What is Important to Teach

What Teachers say about what is important to teach (by Years of Waldorf Teaching Experience) *(Q 1, 2, 9)*	
0 to 3 Years Experience	• Coming to an understanding of concepts through observation, and process.
3 to 5 Years Experience	• Waldorf makes science come alive. • Since I'm learning the curriculum as I go, I really don't know how to answer this or what the difference is. [between Waldorf processes] • Some concepts depending on how you come to the concept.
6 to 10 Years Experience	• Phenomena of science in the 4-7th some conceptual work perhaps creeping into the 8th
Beyond 10 Years Experience	• The whole development of science in 6-8th grades builds a deep awareness within the children. • If you mean process- demonstration, experiment and proper written follow up in scientific form. • The task is to help them develop their powers of observation. • Age appropriate concepts after 6th • Teaching science is more teaching a process, less specific concepts, although concepts are important. • I would say process and observation are more important. Many children already have the concepts. • The students must arrive at the concepts themselves. At the end of a three stage process. • It helps children see how observation, preparation, etc. all the variables can change a result. Very important for not presenting dogma.

Emergent themes:

- Phenomenology as an approach to deepen nature awareness.
- Most important processes are *observation, experimentation, demonstration, & writing.*
- Concepts should emerge from observation of phenomena and be developmentally appropriate.
- Some consider negative experimental outcomes integral to learning, others wonder if it might reflect teacher ineptitude.

Figure 7. Confidence in Teaching Science

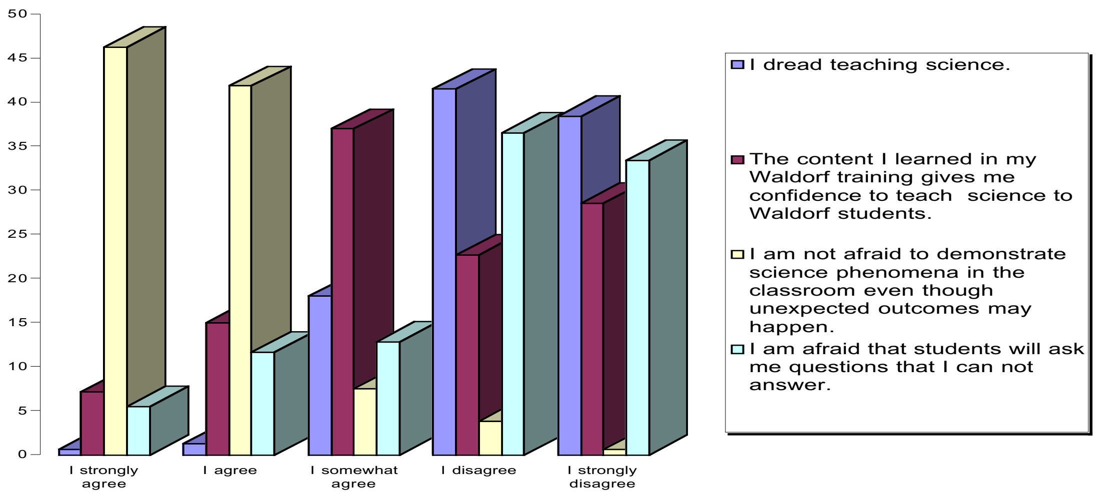


Table 10. Representative Statements on Confidence in Teaching Science

What Teachers say About Confidence in Teaching Science *(by Years of Waldorf Teaching Experience)* (Q 4, 5, 7, 8)	
0 to 3 Years Experience	• I look forward to it but I'd rather eat a typical school textbook than try to teach out of it. • There needs to be a specialty class created for this focus. Also turning marble to calcium oxide has been close to impossible. It seems a set up for failure and a let down for the excitement. • The training only gives an outline of an attitude. More specific scope and sequence needed. • I know they will ask me questions beyond my framework of knowledge, and I encourage them to be asked.
3 to 5 Years Experience	• My Waldorf training indicted ways of teaching not much content. • Not much training. • Better than traditional. • My confidence comes from knowing the resources are out there. • I feel confident due to my own background, not my training.
6 to 10 Years Experience	6 to 10 Years Experience • Just [dread] chemistry because I lack knowledge re safety concerns. • I love science but training was inadequate in this field. • Simply not enough. More emphasis needed both in the training and summer conferences. • One short course and the stud of Goethean science is insufficient. I learned much more from colleagues and the work m own children brought home. • Must always do experiments at home/school day before. • I am clear with my students that I am not an expert but willing to strive.

What Teachers say About Confidence in Teaching Science *(by Years of Waldorf Teaching Experience)* (Q 4, 5, 7, 8)	
Beyond 10 Years Experience	• I would truly enjoy it if supplies were readily available, materials handy and I had access to more guidance. • Depending on the grade level/ block- more confidence with physics less with chemistry. • Mainly I worry about being well enough prepared. • Well I am more effective when I stick to math. • My Waldorf training did not deal all that much with science but our school arranged a week with Roberto Trostli and I went to a science weekend at Washington • My training focused so intensively on stories and early grades that science work was minimal. • My Waldorf training taught me how to teach science, not the content. • I gained enormous confidence after teaching it the first time. The 2nd time I began to figure out what I was doing- by the 3rd time I understood why we teach it the way we do. • I try to use experiments that are fairly reliable, but unexpected outcomes often are very instructive. • I have safety fears and because I do not understand much beyond what is in the curriculum, I don't know too much of what could happen. • It's ok to say you're not sure and need to think about it, but never forget to follow up.

Emergent themes:

- Most teachers look forward to & love teaching science.
- The burden of teaching science does not come from the topic itself but from lack of guidance, training, & physical resources.
- Overall the training received is inadequate: too short, not much on content, mostly on methodology & attitude.
- Most helpful: summer workshops, colleagues, mentors.
- Some teachers are concerned about not being able to answer questions, though most see this as a positive opportunity.

Figure 8. Assessment.

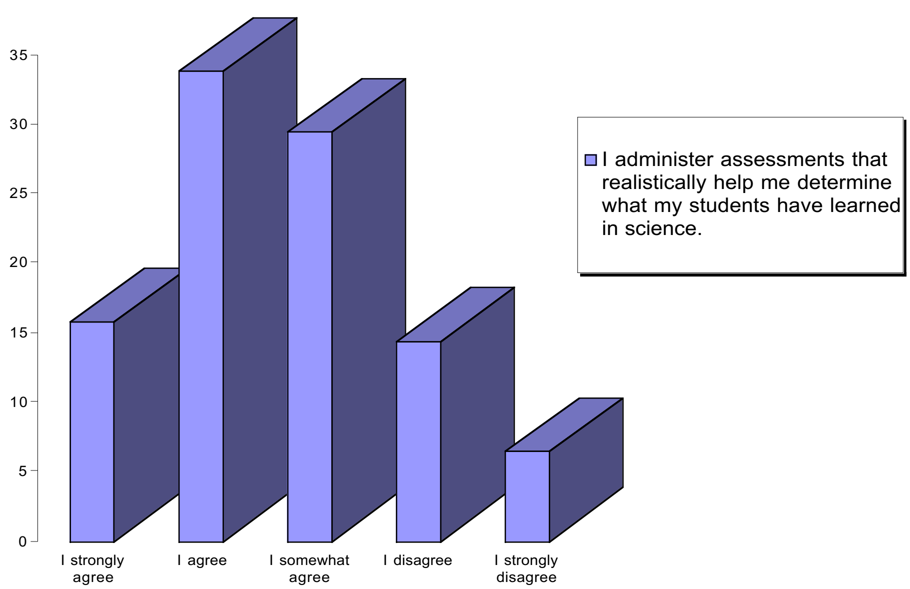


Table 11. Representative Statements on Assessment

What teachers say about assessment (by Years of Waldorf Teaching Experience) (Q 13)	
0 to 3 Years Experience	• I assess constantly but am wary of being too realistic, though I believe that if I am fortunate enough to take my class through 8th grade they will do well in any objective testing they may encounter in high school or beyond
3 to 5 Years Experience	• The assessment question is a tricky one- I think some students may not come to a true understanding of some concepts until their high school years. • I would be interested in knowing how other teachers assess.
6 to 10 Years Experience	• The results of my presentation must cook in the students a while and will frequently reappear years later. • I do give assessments based on what we've done- my students usually do well
Beyond 10 Years Experience	• Yes, but this too is time consuming having to divide exactly what would truly give a useful assessment of these skills • Assessment occurs primarily in follow up discussion, not a formalized fashion

Emergent themes:

- Some see understanding of concepts a concern for high school, not an issue for lower grades/middle school.
- Others express the concern that assessment is time consuming.
- Many suggest that assessment has been problematic & greater knowledge of various methods would be useful.

Table 12. Representative statements from Interview Data (Focus Group & Individual)

Representative statements from Interview Data (Focus Group & Individual)	
Lesson Planning, Preparation, & Implementation	
Student Teacher	• "[teacher preparation] really left me feeling that was a huge hole for me that I had to jump over, and I think it has to get a good science course. • They must discover the "Cause and effect" on their own and not be told how or why by the teacher.
Beginning Teacher	• A lot of the Waldorf text books are too sentimental and don't explain what the teacher is teaching.
Expert	• "by tradition. I am working on a curriculum project, taking Steiner's lectures and moving them by theme. His references are so general, where he uses examples as a way of [unclear] way of learning. I would hope that this would leave teachers free, and I think that he meant to leave teachers free. He showed 6-7 different ways of introducing letters in the first grade. I think that's a model that there should be just as many ways of introducing the natural world of physical phenomena. The curriculum can be as wide open as a teacher's connection to subject and class."
Science Education in the Waldorf Context	
Student Teacher	• It has wonderful images that resonates with me … the whole soul is ... drawing from the moon. That is fine for me, but I don't know what a parent would think. • Coming to an understanding of concepts through observation, and process is important in Waldorf Education. • Phenomenological aspects of science is most important- not dead concepts.
Beginning Teacher	• we lose many students at the 8th grade or younger, they want more challenge in the science s than we provide. • Creating inspiration, kids will make connections themselves, discover for themselves with their internal self-motivation
Master Teacher	• I've been teaching over 20 years and I'm mainly following science teaching step by step, all it can be is a recipe. I don't have a lot of confidence & really need to work with somebody to feel more

Representative statements from Interview Data (Focus Group & Individual)	
	comfortable with what I'm doing. • As I study Steiner…I am more encouraged by doing this because it has to be experienced... the Goethean way of learning, which is out of the phenomena, and out of that comes the statement. Trostli's book outlines the process very clearly. • Specialization for teaching sciences would greatly help both teachers and students.
Expert	• One of the concerns is, I don't know anything about the subject so how can I teach it? They feel it's different to teach, let's say, geology, than it is to teach Roman history. Even if they don't know anything about Roman history, somehow they imagine that since they can read and tell stories, they can learn enough about Roman History, but not geology." • Teachers fear students will know more than them about the topic, and ask questions they can't answer. • Using examples from their lives they can recognize that they know a great deal about the physical world, they just don't call it science.
What do Students Learn and How do you Know?	
Student Teacher	• I think they are developing a thirst for science. What they "should be getting out of science" I'm not sure.
Beginning Teacher	• Parents want to know if its viable. They want a comparison list and examples of how their child is learning science. • importantly I want them to individually and collectively discover these relationships [between phenomena and concepts taught]. And they will, given a chance. • It is hard to assess students; knowing which methods to use.
Master Teacher	• "You can do things in a different way than they are usually done": Use different experiments to teach the same lesson, or just using non-text book methods to teach certain laws of science. • Using writing project at the end of a block, which could be considered an assessment. " What I know now, and what I knew before" Another writing assignment: " I never realized…" Assignment is to finish the sentence. • Steiner emphasized that only through the artistic, can these concepts be clearly understood. • It's important to learn that the world is not a foreign entity. It is important for a child to see there is an order to things. When we did mechanics I put my car in the middle of the field with teams of boys and girls. Gave them pulleys, levers, shovels everything and said lets see who can move the truck 20 feet first. The boys came up with many sophisticated ideas using the pulleys, lifting things up, etc. The girls went over and started pushing the truck; they actually won because they got it there first. Questions after ward were what does that have to do with Mechanics? …let's find out. We got into the development of the wheel and so on...
Expert	• We are using the science content, just as we use history or grammar content to help them order their thinking, help them think in cause and effect, to help them probe deeper to extend farther so that they are using it as a tool to really explore new [unclear] of thought • The basic science syllabus is taking the college level course and watering it down so that a preschooler can understand it.
Waldorf Science Education in the Mainstream Context	
Student Teacher	• Offers more than the mainstream curriculum.
Beginning Teacher	• Standardized tests fail to measure science- Gives o indication of what students learned in Waldorf schools. • Waldorf standards encourage enthusiasm.
Master Teacher	• Waldorf encourages a love of learning, kids stay engaged. What are we trying to teach at grade x? Problem across board, not isolated to Waldorf Waldorf teaches more than just the standards.
Expert	• I would venture to say that the results are not going to be profoundly different from the general population, nor should they. Ideally, the reason one becomes a botanist is not because of the botany courses they've had, but because it is their destiny. One would hope that we'd give these children a chance to fulfill their destiny • The fact is the educational system doesn't have people learn very much for their lives. They've learned a lot along the way, but by the time they're adults they've either repressed or forgotten most of what they've learned because it is so distasteful- the process which they're getting."

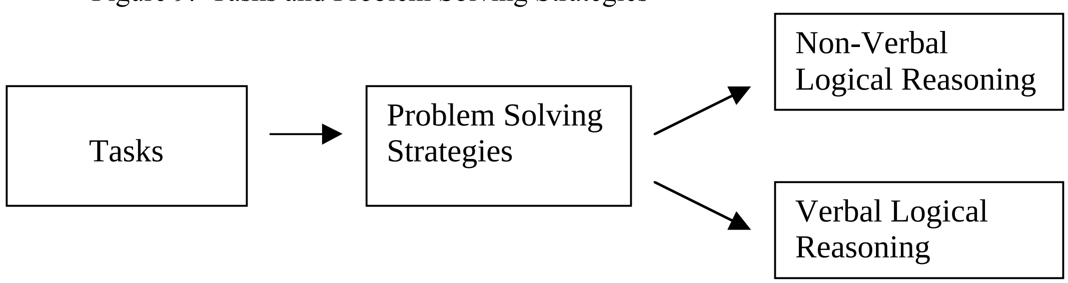
CHAPTER 5

In the Classroom

Data.

1. Non-verbal Logical Reasoning Task (TONI)
2. Verbal Logical Reasoning Tasks
3. TIMSS Magnet Task
4. Videotapes of Waldorf science lessons.

Figure 9. Tasks and Problem Solving Strategies



Procedures

Task 1: Non-verbal Logical Reasoning Task.

This task served as a base-line in the present study, and was administered to traditional public school students and Waldorf students to see if there was any significant difference in the way Waldorf students use processing strategies in Non-Verbal Logical Reasoning Tasks compared to their public school counterparts. The subjects were expected to examine the differences and similarities among the figures in the set and in the response alternatives, to identify a rule that was operating, and, on the basis of that rule, to select the correct response. Rules governing the relations in the set varied among the items and, in some cases, more than one rule was operating in an item. For example, in one case the subjects were expected to detect the characteristics of shape and shade. In this case, there are three circles, two triangles, and three squares. Each type of shape has three shades: white, lined, black. What is missing from the stimulus set is a triangle with lined shade? Therefore, this item requires subjects to pay attention to both the overall pattern of change in figures and the shading details.

There are 50 items in the TONI test, arranged from the easiest to the most difficulty level. Due to the limitation of time for administering tasks in the classroom and the specific purpose of the present study, only 17 items containing more than one operation factor (e.g., shape and rotation) were randomly chosen for this study. Two additional items were created to make up a total of 19 items. Of the 19 items, 3 were used as protocol-eliciting items for later analysis of reasoning strategy. Each of these 3 items contains a question asking the subject's reasoning strategy for that particular item. Protocol analysis is a technique developed by Newell and Simon (Newell & Simon, 1972) to record subjects' ways of solving a problem. Typically, their protocol was obtained through think-out loud activities and the verbatim transcript provided the basis for analysis. Since the Non-Verbal Logical Reasoning Task in the present study was a group task, talk-out loud activities would be hard to obtain. Therefore, protocols were obtained through a forced-choice question. The subject, after choosing the answer, was asked to answer the additional question: "What did you notice first? (1) the change of the shape (2) the black dot." Notice that answer (1) represents the subject's strategy of attending to the overall pattern (Whole-First) while solving the problem, whereas answer (2) represents the subject's tendency to notice inside-shape details first (Part-First). Accordingly, a simplified protocol would be obtained. It is not assumed here that the subjects were consciously aware of the order in which they noticed things, but that the recall of attention order would reflect to some extent psychological preference for perceptual cues.

The Non-Verbal Logical Reasoning Task was given first, immediately followed by the Verbal Logical Reasoning Task. The given order was based on the rationale that the pictorial task might be more interesting and, therefore, motivate the subjects to go on to the verbal task. The verbal task then would prepare the subject for the Computer Task, which is a timed verbal task.

There is no reading, or verbal writing required in the administration of the Non-Verbal Logical Reasoning Task or in the subjects' responses, except for writing the number of the answers chosen. First, the examiner stood in front of the test room holding up a 36" x 42" demonstration board with practice items on it. The examiner then read the instructions and pointed to a set of figures on the demonstration board: "Here is a set of figures, please examine the differences and similarities of these figures to find a set of rules that is operating among these figures. Please identify which is the missing figure from the following choices." Three practice items were given on the demonstration board and the subjects were encouraged to join the examiner in pointing to the appropriate response. The correct responses were announced but not explained, and the subjects were instructed to start the actual task. Subjects were reminded prior to the paper-pencil task session that they were expected to work at their own pace and independently, without talking to each other.

Task 2: Verbal Logical Reasoning Task.

Immediately after the Non-Verbal Logical Reasoning Task the subjects were instructed to go on to the Verbal Logical Reasoning Task, since this task was in the same booklet. Students were also administered an inference task, in which they were given a scenario with various pieces of evidence, then asked to suggest or predict a possible outcome based on that evidence. Talk aloud responses were allowed; researchers recorded what was said. At the end of the tasks researchers facilitated debriefings and recorded student responses.

Task 3: TIMSS Magnet Task.

The TIMSS Magnet task was administered to 4^{th}, 6^{th}, and 8^{th} grade students at 4 Waldorf schools in California and 1 in Hawaii. One of the California schools was a Waldorf public methods school representing diverse student in a low SES school; all other schools were private Waldorf schools which had been in existence a minimum of 11 years. The tasks were administered during one 45 minute periods in each grade, with identical grade level instructions, task forms, and materials provided. For the magnet task students were given 2 magnets and various materials and asked to indicate which magnet was stronger, and to describe different ways they figured out which magnet was stronger. Data sheets were provided for their responses. The administration protocol followed the original TIMSS protocol as closely as possible. As stated in the TIMSS document, the task "…was intended to measure problem solving in both strategy development and its implementation, and the ability to support the conclusion with evidence. Eighth-grade students were asked to experiment with the magnets and materials, without any directive as the number or type of experiments, whereas fourth-grade students were asked to test magnets in two different ways (Harmon et al., 1997, p.21)".

Inquiry in the Classroom (Videotaped lessons)

Videotapes of science lessons were conducted at school sites in Hawaii, California, and Massachusetts. Teachers were encouraged to conduct lessons as they typically would do so, and students were encouraged to go about their activities as usual. Researchers were as unobtrusive as possible, placing a small digital video camera on a tripod in the corner of the room. Entire science main lessons were taped and analyzed according to the CLM Inquiry Analysis Codes identified in *Table 15*. The taped lessons were coded according to what inquiry category was addressed and the number of minutes. Researcher notes also recorder student voices, teacher voice, and the nature of what was happening. At the conclusion of each taped session minutes and percentages of total time were calculated for each inquiry category and subcategory.

Analysis

1. Verbal Logical Reasoning Task

A total of 40 Waldorf students responses were compared to 40 public school student responses. Two forms were used to discourage copying.

Table 13. Subjects for the Verbal Logical Reasoning Task

Group	Form A (n)	Form B (n)	Subtotal
Waldorf	20	20	40
U.S. Public School	20	20	40
Total (n)	40	40	80

2. Non-verbal Logical Reasoning Task.

Each item was scored as (1) correct or (0) incorrect. The original responses for each subject were recorded for later error analysis. For the protocol items (Items 17-19), additional coding was given besides each response. The protocol coding scheme is shown in Table 14.

Table 14. Scoring Scheme for the Protocol Items 17-19

Item	Protocol Questions: "What do you notice first?"	Response Type	Coding for Analysis
17	(A) detail shape-change	Part-First	2
	(B) pattern of shaded area	Whole-First	1
18	(A) the little shaded squares	Part-First	2
	(B) the pattern of the lines	Whole-First	1
19	(A) the change of the shapes	Whole-First	1
	(B) the black dot	Part-First	2

Each item on this task was also scored as (1) correct or (0) incorrect.

3. TIMSS Magnet Task.

As in the original TIMSS test, only the first correct experiment was used to compute a student's score. Students received one point for identifying the correct magnet and one point for including at least one correct description or diagram showing how the results were interpreted. Quantitative data were compiled to correspond to the format used in the TIMSS data analysis so that comparisons could be made. Qualitative data (student diagrams and narrative responses) were
Analyzed using CCA to identify common themes and representative problem-solving strategies.

4. *Inquiry in the Classroom.*

Videotape data were analyzed and coded according to the Inquiry Analysis Codes provided in the table below. These categories are adapted from Peters' and Gega's (Peters & Gega, 2002) well grounded research in classroom processes of science inquiry. Tapes were viewed in 1 minute sweeps and coded according to the criteria most closely resembled. At the end of the taped session each category was then totaled. Additionally, representative and/or other clarifying statements and actions were entered into the data sheet.

Table 15. The Constructivist Learning Model

Invitation	**Exploration**	**Proposing Explanations & Solutions**	**Taking Action**
1. Observe surrounding for points of curiosity 2. Ask questions 3. Consider possible responses to questions 4. Note unexpected phenomena 5. Identify situations where student perceptions vary	1. Engage in focused play 2. Brainstorm possible alternatives, problem solving 3. Look for information 4. Observe specific phenomena 5. Design a model 6. Collect, organize, analyze data 7. Select appropriate resources 8. Design and conduct experiments, investigating 9. Engage in debate 10. Identify risks and consequences	1. Communicate information and ideas 2. Construct & explain a model 3. Construct a new explanation 4. Review & critique solutions 5. Utilize peer evaluation 6. Assemble multiple answers/ solutions 7. Determine appropriate closure 8. Integrate a solution with existing knowledge and experiences	1. Make decisions 2. Apply knowledge and skills 3. Transfer knowledge and skills 4. share information and ideas 5. Ask new questions 6. Develop products and promote ideas 7. Use models and ideas to elicit discussions and acceptance by others.

Findings

1. *Verbal Logical Reasoning Tasks*

The mean performance on the Verbal Logical Reasoning Task for the two groups is presented in Table 16. A t-test result indicated that the overall performance for the two groups does not display any significant difference ($t(47) = 1.03$, $p > .01$), but the variation and standard deviation within-group is greater for the Waldorf group(Waldorf, $M = 12.55$, $SD = 4.23$; US, $M = 12.31$, $SD = 3.89$).

Table 16. Mean Performance on Verbal Logical Reasoning Task

	Group	Mean	SD
Syllogisms	Waldorf	5.90	1.89
	US Public	6.15	1.77
Inferences	Waldorf	6.15	2.47
	US Public	5.72	2.64
Total	Waldorf	12.55	4.23
	US Public	12.31	3.89

Mean scores for the Waldorf and Public School students are 12.55 and 12.31, respectively. Notice that the whole test is divided according to 2 kinds of logical reasoning tasks, and different t-tests were performed according to the comparison scheme depicted in Table 17, and the t-test results are reported in Table 18 to Table 21.

Table 17. Comparison Scheme for t-test

Public School	vs.	Waldorf
Syllogism vs. Inference	vs.	Syllogism vs. Inference
Syllogism	vs.	Inference
Inference	vs.	Syllogism

Table 18. Within group t-test (paired)--Compare Syllogism and Inference

Group	t value	p value
Waldorf	.51	.611
Public	1.04	.306

Table 19 Between group t-test (paired)--Compare Syllogisms

Group	Mean	SD
Waldorf	6.65	.375
Public	6.20	.296

$t(38) = 0.97$ $p = 0.338$

Table 20. t-Test paired (within group)--Compare Inferences

Group	Mean	SD
Waldorf	8.00	.290
Public	7.55	.438

$t(38) = 0.81$, $p = 0.398$

Table 21. t-Test paired (within group)--Compare Overall Performance

Group	Mean	SD
Waldorf	12.55	4.16
Public	12.31	3.57

t(76) = .95, p = .349

2. Non-verbal Logical Reasoning Tasks

The design of the Non-Verbal Logical Reasoning Task, was a between-subject design administered to subjects in which basically every subject was given the same task and the main focus of this task was on the error analysis across items.

As shown in Table 22, the Waldorf group performed somewhat better than the U.S. group t(78) = 5.22, p = .0001. Means for the Waldorf and the Public School groups were 6.90 (SD = 2.09)and 6.35 (SD = 2.82), respectively.

Table 22. Mean Comparison of Performance for Public School and Waldorf groups

Group	Mean	SD
Waldorf	6.90	2.085
Public	6.35	2.282

t(78)=5.22, p*=0.0001

Both groups were given three protocol items asking if they noticed certain features first (part-first vs. whole-first) while they were solving the problems. Even though not all three items significantly between group difference in part-whole protocols responses(according to Chi-Square tests, item#17: $X^2(1, N = 77) = 4.62$, $p < .05$); item#18: $X^2(1, N = 77) = 1.61$, $p > .05$; #item19: $X^2(1, N = 77) = 171.18$, $p < .0001$), a Chi-Square test on overall responses ($X^2(1, N = 231) = 17.88$, $p < .0001$) indicated that the Waldorf group preferred the “Part-First” strategy and the Public School group preferred the "Whole-First" strategy-- that is, the mean percentage of protocol responses of "Part First" was 60.0% for Waldorf and 41.7% for Public School students; the mean percentage of protocol responses of “Whole First” was 40% for Waldorf School students and 58.3% for Public School students. Table 23 shows how the percentages broke down for each of the 3 protocol items responses.

Table 23. Comparison of Protocol Items Responses (%)

Item	17		18		19		Overall	
Type	PF	WP	PF	WP	PF	WP	PF	WP
Public	35	65	45	55	45	55	41.67	58.33
Waldorf	59	41	59	41	62	38	60.00	40.00

PF=part-first strategy WF=whole pattern-first strategy

To further investigate the differences in logical reasoning patterns between these two subject groups, an item analysis was performed. First, all the items were grouped together according to common features followed by a correct rate for each group in order to see the general performance pattern between groups (see Table 20): Group A items require subjects to intersect parts of figures from the rows and columns; Group B items require subjects to see the progressive change of direction among figures; Group C items involve shape and shade changes among figures in each cell; Group D items involve figure changes by adding or subtracting one or more attributes; Group E and F items involve classification of the stimuli figures; Group G items are pattern recognition of figures. All group items except Group B items are examples of part-whole relations of the type likely to be relevant to the logical reasoning strategies of relative clauses as indicators of part-whole relations.

The mean correct rate for item groups (Table 24) indicated that it is only on Group B that the Public School group ($\underline{M}$ = 40) outperformed the Waldorf group ($\underline{M}$ = 28.33). As described above, the Group B items require subjects to pay attention to the progression of figures and do not require the distinction of a part-whole relation of figures like the other item groups. These results can be interpreted as indirect evidence that when items involve part-whole relations, the Waldorf group outperformed the Public School group.

Table 24. Averaged Correct Rate for Each Item Group

Group (item numbers)	Waldorf (%)	Public School(%)
Group A (1, 5)	41.25	37.50
Group B (3, 6, 8)	34.33	40.00
Group C (2,11)	27.75	17.50
Group D(9,12,14,16)	48.00	41.88
Group E (10, 15)	61.25	55.00
Group F (4, 7)	48.75	41.25
Group G (13)	54.55	35.00

3. TIMSS Magnet Results:

Table 25. TIMSS magnet Results.

Grade	Total *n*	% Correct	% Correct Description & Interpretation
Waldorf 4th	67	81	73
U.S. 4th	777	82	65
International Average4th	5,637	80	64
Waldorf 6th	36	78	94
U.S. 6th	na	na	na
Japan 6th	na	na	na
Waldorf 8th	89	98	98
U.S. 8th	712	90	81
International Average 8th	10,279	92	88

Figure 10. Comparison Scores of Percent Choosing Correct Magnet

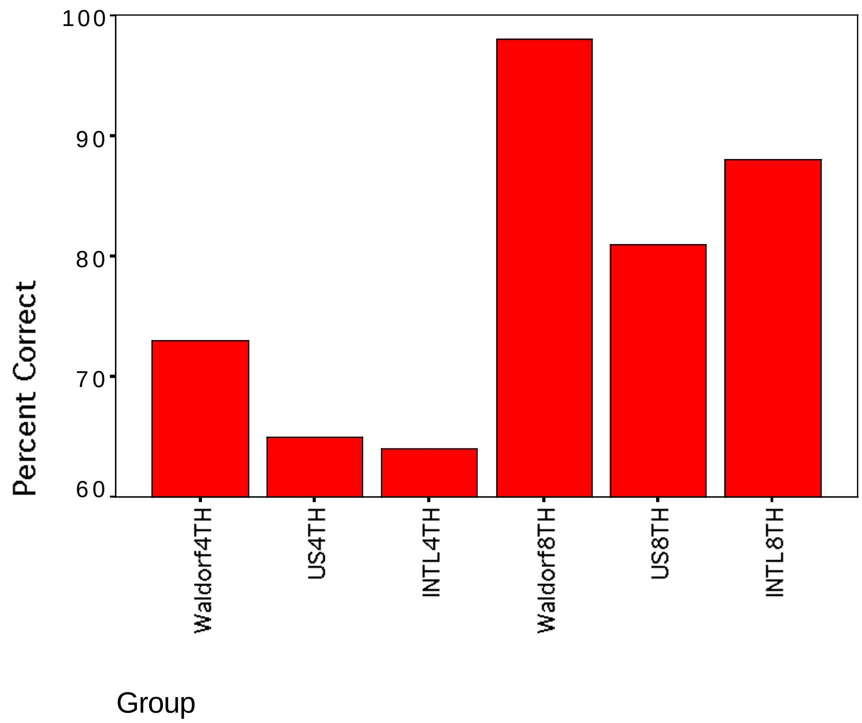


Figure 11. Comparison Scores of Percent Providing at least 1 Correct Magnet Solution

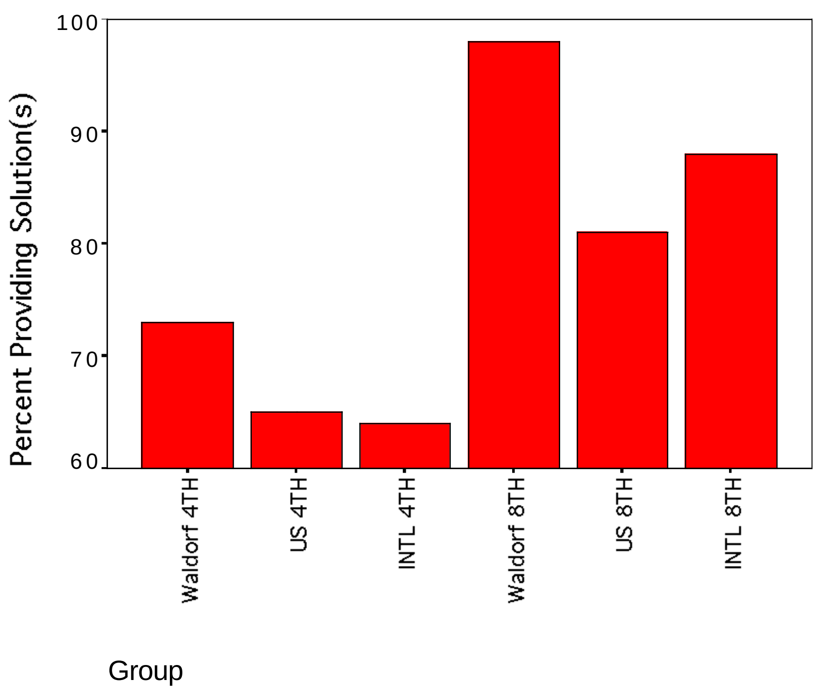


Table 26. Sample Student Narrative Responses to TIMSS Magnet Task

Sample Student Narrative Responses to Science Magnet Tasks	
Grade 4	• The ball went to the A magnet first. • the A magnet got all the stuff first. I think the A magnet is stronger. • A can hold 5 washers. B can hold 4 washers. • A can make the ball move from to inches away. B can make the ball move from 8 inches away. • I put A top of B and A got B together and I put some stuff and A got more stuff. • I think that B is stronger cause I tried to put a nail through the hole in to see what one is stronger. And you had to get really close with A magnet but with B magnet you could stay kind of away.
Grade 6	• I used my ruler to measure how far away the A magnet could attract the washer ad the paper clip. I used my ruler to measure how far away the B magnet could attract the waster ad the paper clip. • (t2) I used the poker chips to pile up on top of the magnets and see how may the magnets could hold the washer through. • I held magnet A about 3cm above a paperclip and slowly lowered it down. Did the same with magnet B. At about 2cm, magnet A "sucked" it up. At about _ cm above the paperclip, the paperclip got "sucked" up. • I held the magnet (A) on top of a poker chip and placed a magnet ball under. I did the same thing with magnet B The magnet (A) held the ball through the chip. • It (magnet B) couldn't hold the ball. • I picked magnet A up with the two nails, I tried to see how many objects it could pick up at one time. I tried the same thing with magnet B. It (magnet A) could pick up 5 paper clips and 2 washers. It (magnet B) could not pick up anything, it could hardly hold on to the nails. • Magnet A is stronger size for size but magnet B has more surface area to grip so it can hold more (weight) But if it were between which one could hang onto a magnetic (ceiling) I think A would win. • I put all the washers, paper clips and nails together and saw what each magnet was able to pick up. Magnet A was able to pick up 4 washers 5 paper clips and 2 nails. Magnet B was able to pick up 6 paper clips and 3 washers. • Placed round chip between magnet A and washer and turned magnet upside down. Magnet B did the same thing. Washer stayed attached to magnet A through chip. With magnet B, washer and chip fell off.
Grade 8	• I put a paper clip in between the two magnets and slowly moved both of them closer t the paper clip an equal distance using the ruler. • I used the ruler, the magnets A&B, 2 paper clips and a nail. • I put the ruler down. • I put a magnet at 0mm • I slowly put the object 1mm close to the magnet at a time and wrote down at which distance the object went to the magnet. • I laid all the items in the bag in groups on my desk and took the B magnet and drug it an inch over all items and did the same with the A magnet. • I stacked paper clips on B, I could only stack up to 3 paper clips before they started to fall off. I stacked 5 paper clips on A, I only stopped stacking 'cause it got too crowded on the magnet. • I stacked the washers up and placed a ball on top. Then, taking magnets A and B, I used them to try and pull the pile up. Magnet A pulled up the ball and three washers. Magnet B pulled up nothing. • Gave each magnet a score according to the 5 tests. A received a score of 93, and B received a score of 28. • Couldn't shake the ball off magnet A. The ball shook off very easily from magnet B. • Magnet A picked up 6 washers right off the bat, where magnet B struggled to pick up two. The paper clips being lighter were more easily picked up but the ratio of about 6:2 was about the same. • I lined up all of the 10 washers in a row, two wide and 5 long. I then passed both magnets over them at the same height. Magnet A picked up 6 washers right off the bat, where magnet B struggled to pick up two.

4. Results of Videotape analysis

Figure 12 indicates the total percentage of instructional time devoted to each of the 4 main inquiry categories. Table 27 to Table 29 summarize three statistical perspectives. Figure 13 to Figure 16 display the variations from school to school.

Figure 12. Percentage of Instructional Time per Inquiry Categories.

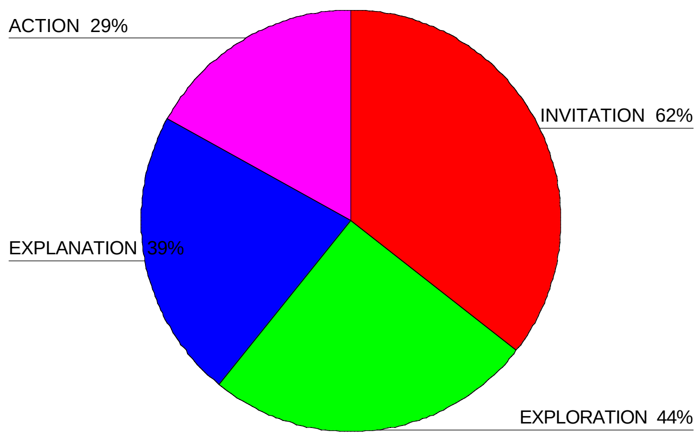


Table 27. Inquiry Analysis Statistics

	INVITATION	EXPLORATION	EXPLANATION	ACTION
N	4	4	4	4
Mean	.6150	.4400	.3875	.2925
Median	.5950	.4250	.3650	.3000
Mode	.56	.31	.26	.21
Std. Deviation	.007	.1197	.1517	.062
Variance	.044	.014	.023	.004
Range	.15	.29	.30	.15
Minimum	.56	.31	.26	.21
Maximum	.71	.60	.56	.36

Table 28. Mean Ratings of 4 comparison classes

		INVITATIONION	EXPLORATION	EXPLANATION	ACTION
Class # 1	Mean	.5600	.3100	.5600	.2100
Class # 2	Mean	.7100	.6000	.2600	.3600
Class # 3	Mean	.5800	.4200	.4700	.3100
Class # 4	Mean	.6100	.4300	.2600	.2900
Total	Mean	.6150	.4400	.3875	.2925
	N	4	4	4	4
	Std. Deviation	.06	.1197	.1517	.06

Table 29. Correlations of Inquiry Categories

		INVITATION	EXPLORATION	EXPLANATION	ACTION
INVITATION	Pearson Correlation	1.000	.966	-.787	.831
	Sig. (2-tailed)	.	.034	.213	.169
	N	4	4	4	4
EXPLORATION	Pearson Correlation	.966	1.000	-.793	.946
	Sig. (2-tailed)	.034	.	.207	.054
	N	4	4	4	4
EXPLANATION	Pearson Correlation	-.787	-.793	1.000	-.742
	Sig. (2-tailed)	.213	.207	.	.258
	N	4	4	4	4
ACTION	Pearson Correlation	.831	.946	-.742	1.000
	Sig. (2-tailed)	.169	.054	.258	.
	N	4	4	4	4

* Correlation is significant at the 0.05 level (2-tailed).

Figure 13. Percentage of Time Each Class Devoted to "Invitation".

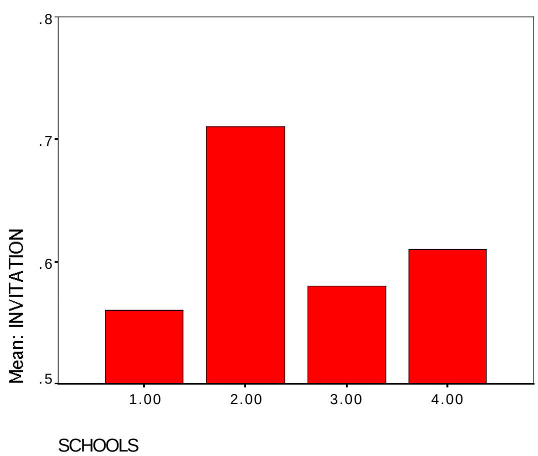


Figure 14. Percentage of Time Each Class Devoted to "Exploration"

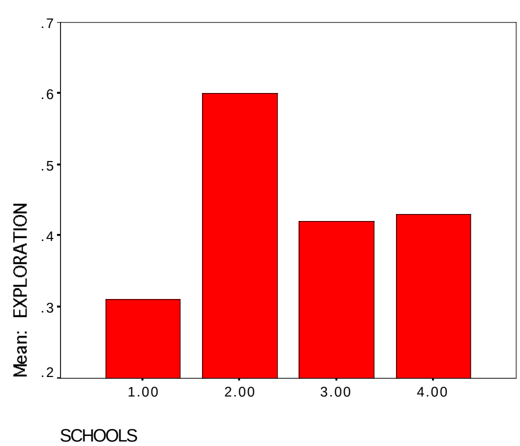


Figure 15. Percentage of Time Each Class Devoted to "Explanation".

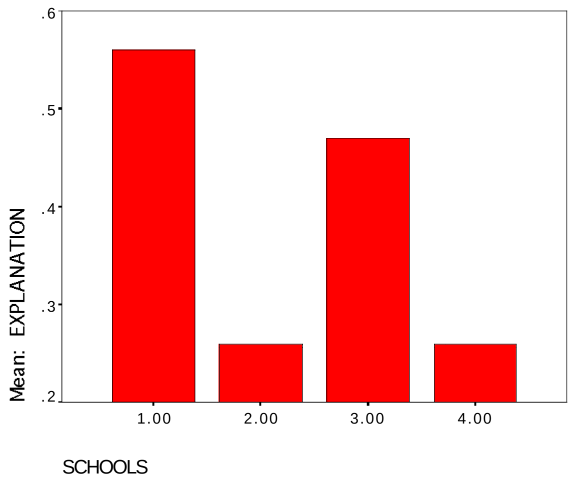
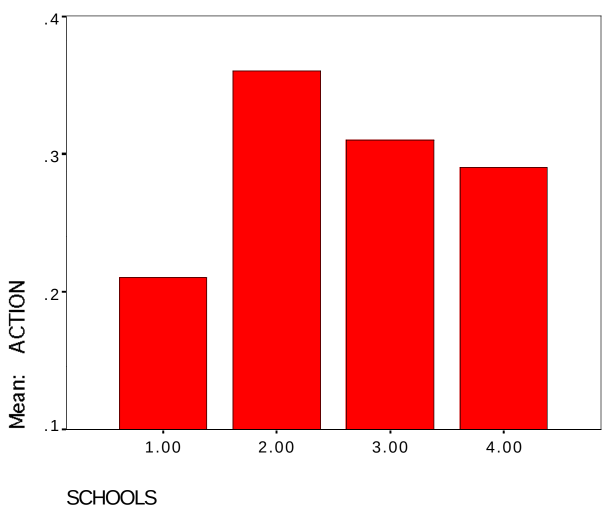


Figure 16. Percentage of Time Each Class Devoted to "Taking Action".



While the above statistical and graphic representations provide reasonable summary information for the 4 main inquiry categories, it is helpful to consider the sub categories as well. The figures below depict that information. The written numbers (one, two, three, etc.) correspond to the numbers under each inquiry category in *Table 15*. If a number is missing it is because nothing was observed in that category.

Figure 17.

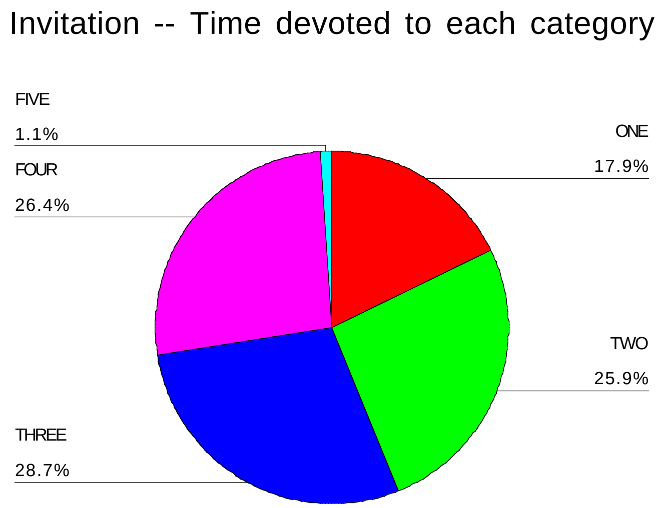


Figure 18.

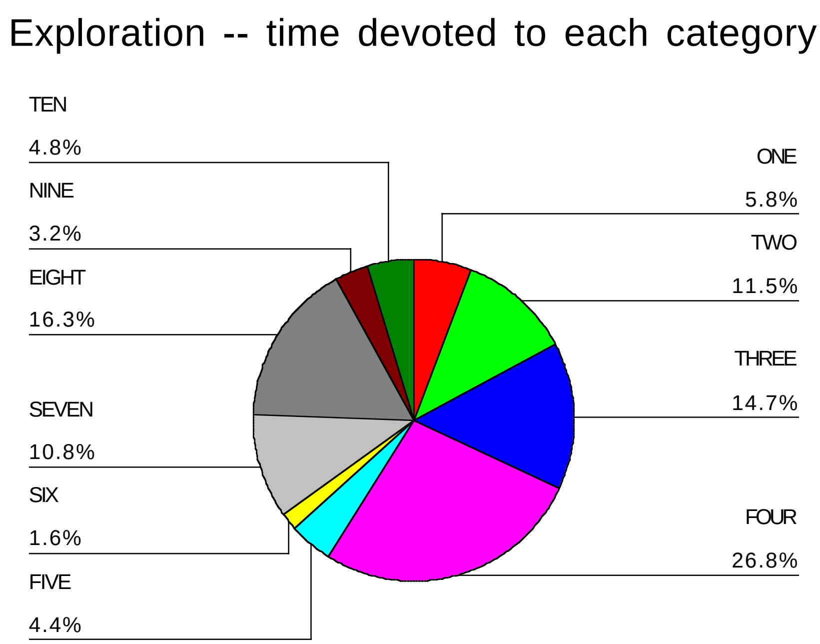


Figure 19.

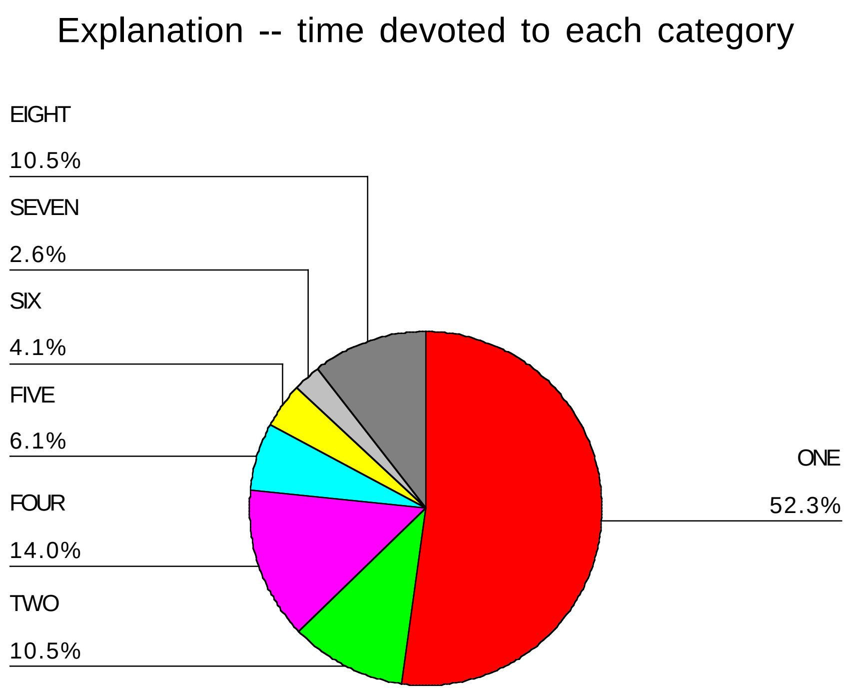
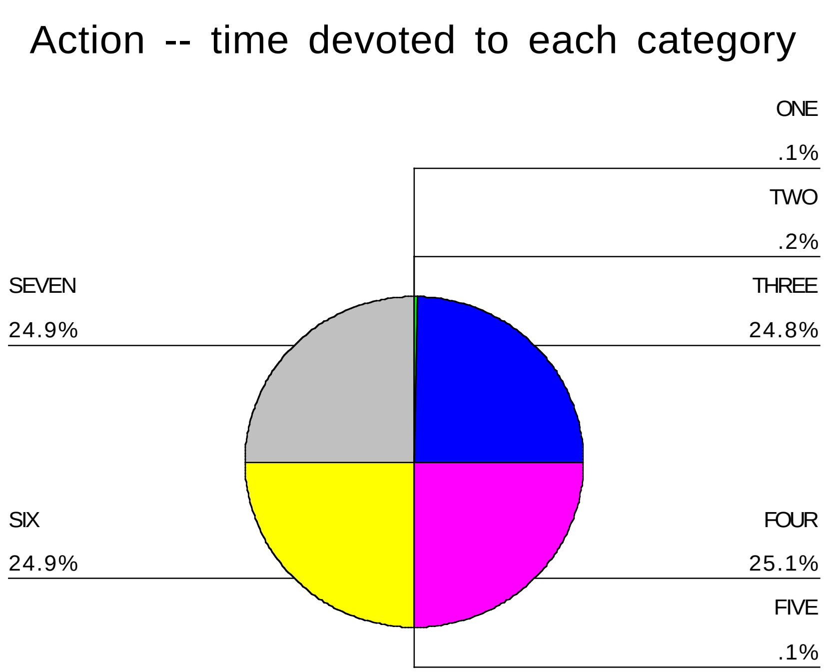


Figure 20.



CHAPTER 6

Discussion of the Findings in Relation to the 4 Research Questions

This paper began with the four primary questions:

1. How does the Waldorf science curriculum align itself with state and national science standards?
2. What are the perspectives of Waldorf students, parents and teachers regarding science education in the Waldorf context?
3. How do Waldorf students' scientific reasoning and problem solving skills compare to those of their counterparts in mainstream educational settings?
4. Does Waldorf offer a viable form of science education?

This section seeks to answer each question by walking through the pertinent findings from each of the three sub-studies (*Curriculum & Assessment; Surveys & Interviews;* and *In the Classroom*).

How Does the Waldorf Science Curriculum Align Itself with State and National Science Standards?

Using Inquiry as presented in the National Science Education Standards, as discussed in the *Curriculum & Assessment* section, the mean percentages for *pedagogical appropriateness* for the Waldorf science curriculum overall was 84%, with a range of 70% for grades 4-5 to 84% for grades 1-3 (See Table 2 and Figure 2). Of the 11 review questions pertaining to pedagogical appropriateness, the questions with the lowest minimum mean (55%) revolved around whether or not the curriculum materials contribute to the development of scientific reasoning and problem-solving skills, and the incorporation of effective strategies to assess student learning. The narrative data (see Table 5) indicate that while the reviewers did not necessarily see extensive evidence to demonstrate standards alignment, they were impressed with the high student engagement activities such as nature walks, farming, and home building. Narrative responses for grades 4 to 8 were generally supportive, although the reviewers questioned certain premises, such as how the activities actually support scientific inquiry. It was noted that the teacher tends to guide the learning process; i.e., too much reliance on demonstrations, too much "telling" the students what they learned. There were also concerns expressed about philosophical and religious imagery in the curriculum (see, for example, the university science educator's responses for grade 7). Also, the accuracy of certain science concepts were seriously challenged (e.g., the implication that there are degrees of life in your body, with the bones being the most "lifeless"). The high school curriculum received a mean score of 80%, with the reviewers providing an overall favorable narrative response, citing strong emphases on experimentation, demonstrations, observations, and science content. Questions were raised about the lack of some pedagogy – uses of technology, for example. When the curriculum was considered as a whole for pedagogical appropriateness, the reviewers expressed encouraging promise provided the science-philosophy dichotomy is addressed.

Based on the mean percentages of reviewers' ratings for *science content,* grades 4-5 were again rated the lowest, at 66%; grade 8 the highest, at 83% (see Table 3 and Figure 3) . Of the 8 review questions regarding *science content* the question with the lowest mean score was # 4, "Does the background material for teachers address the science content that is taught, as well as common misconceptions?" The question receiving the highest mean was # 5, "Is the treatment of content appropriate for the grade level?" The mean score for question #3, regarding consistency of the content with the National Science Education Standards, was 71%, with a range from 60% to 80%. Narrative responses (see Table 6) revealed concern around the accuracy of some concepts (e.g., anthropomorphic and religious imagery treated as accurate science content, the presentation of animals as representative of aspects of the human being.). There was appreciation for the imaginative element present, particularly in the lower grades, though Waldorf "bias" was expressed. (See for example, the Biologist's statement for grades 4-5: "…the content is highly colored by the philosophy of Waldorf.") While there was a sense that reasonable content was addressed, numerous examples of science standards not addressed were cited (the narrative data in Table 6 provides these examples). Numerous concerns are also expressed in this same data set related to the strong Waldorf philosophical bent. For example, as the Environmentalist asked for grade 9-12, "Where do the teachers find out about how organs relate to the life of the soul and spirit? You won't find that in your common biological text."

Mean percentages of reviewers' ratings for *presentation and format* were the lowest of the three main categories, with mean scores for six of the eight questions below 50% (see Table 4). Grades 4 to 5, as with the previous 2 categories, received the lowest overall mean score (66%). Grade 8 received the highest overall mean score of 83%. The range for some questions differed by as much as 50%, indicating highly varied interpretations. A review of the narrative responses (see Table 7) provides an explanation for these varied interpretations – the reviewers expressed a lack of sufficient material to make the necessary judgments. To gain a more accurate picture of curriculum *presentation*, therefore, we turn our attention to the analysis of classroom teaching found in the *In the Classroom* section.

When videotaped Waldorf science lessons were analyzed according to the Constructivist Learning Model in Table 15, the percentage of instructional time per inquiry category was 29% for "Taking Action", 39% for "Explanation", 44% for "Exploration", and 62% for "Invitation" (See Figure 12). While there is no prescribed amount for these categories, any category with a noticeably lower or higher percentage than another should be a red flag. 29% for "Taking Action" falls within an acceptable amount, and a strong argument can be made that 62% for "Invitation" is still reasonable since much attention needs to be give to drawing students in as a means to engage them throughout the scientific inquiry process. However, as Figure 13 through Figure 16 reveal, there are significant variations from class to class for each inquiry category. This is further evidence in the statistics in Tables 27 and 28, where “Taking Action” rated as low as 21% for one class and “Invitation” reached as high as 71% in another class. These extremes suggest an imbalance in the focus of delivery of the curriculum for some classes.

From the more detailed analysis of “Invitation” in Figure 17 it can be seen that a minimal amount of time (1%) is devoted to identifying situations where student perceptions vary. This minimal attention to variations in student perceptions, or viewpoints, is reflected again in “Exploration”, where 3.2% is devoted to engaging in debate (see Figure 18), in “Explanations” where 0% was devoted to constructing new explanations (see figure 19), and in “Taking Action” where .1% was devoted to asking new questions. However, over 50% of “Invitation” was devoted to asking or considering responses to questions and 75% of “Taking Action” was devoted to sharing information and ideas, asking new questions, and using models and ideas to elicit discussions.

The correlation findings in Table 29 raise another interesting question about the 4 inquiry categories, i.e., is the percentage of time devoted to one category positively correlated to the percentage of time devoted to another? As the findings indicate, “Invitation” and “Exploration”, “Invitation” and “Action”, and “Exploration” and “Action”, are all positively correlated; suggesting the likelihood that the more time devoted to one variable of the equation will increase the chances of time devoted to the other. Perhaps more intriguing are the negative correlations between “Invitation” and “Explanation”, “Exploration” and “Explanation”, “and “Action” and “Explanation”. Note that in all three of these pairs of negative correlations the more time devoted to “Explanation” there is the likelihood that less time will be devoted to “Invitation”, “Exploration”, or “Action”. The point being that there is the possibility of a predictive component and should the need arise to obtain more of a balance in instructional delivery this correlation table might help. It should also be noted, however, that none of the correlations were statistically significant, indicating that more data will be necessary to substantiate these statistics.

What Are the Perspectives of Waldorf Students, Parents and Teachers Regarding Science Education in the Waldorf Context?

Student perspectives. Our researchers had the opportunity to interact with Waldorf students during the administration of the magnet and logical reasoning tasks and to observe students during science lessons. Based on these interactions and observations plus informal interview data and anecdotal statements the general impression is that the majority of Waldorf students are confident and enthusiastic about doing science, though mixed in their ability to understand, know and apply scientific concepts. Much can be inferred about student perspectives based on how they go about solving scientific problems and how they express the results. The narrative responses in Table 26 provide one such measure. The next section addresses these perspectives in more detail, thus the reader is directed to that section for further discussion.

Parent perspectives. Interaction with parents occurred on an informal basis – i.e., no interview protocol or other systematic form of data collection were employed. The brief discussion which follows, though anecdotal, is included because it underscores two intriguing considerations worthy of further exploration in future studies.

First, the range of parent understanding, commitment and/or support of Waldorf methods varies widely. At one end of the spectrum parents know little, if any, about the purpose and methods of the Waldorf approach, and as long as their children are doing well need to know little else. At the other end parents are fully immersed in the intricacies of their children's education specifically because they are drawn to Waldorf methodology.

Among the parents we conducted in-depth conversations with were a Princeton University scientist, an internationally renowned curriculum author, and other academics. These individuals were asked "Why Waldorf?" and "Are there shortcomings in the science curriculum?" Why Waldorf revolved around the notion that Waldorf offers a nurturing environment, it stimulates imagination, is creative and generally supports the healthy development of the children. Are there shortcomings in the science curriculum generally received an affirmative response primarily due to currency – i.e., Waldorf teachers tend to base their teaching on dated information and either choose to ignore or do not know current perspectives of science and science education. In several cases these parents had tried to encourage the implementation of additional science methods, with lukewarm response. The general perception these parents expressed is that the Waldorf teachers had a reason for teaching the content they teach in the way they teach it and there is neither time nor inclination to add more. There was also some concern about misconceptions – both student and teacher – particularly when teachers rationalized that this was okay because the science concepts are secondary to the means in which they are taught. In spite of these shortcomings these parents still felt that Waldorf held great promise, particularly if open minded conversations about science content and delivery could occur. As the Waldorf teacher interview and survey data, discussed below, suggest -- there is openness, even encouragement, for this process to occur.

The second intriguing consideration revolves around Waldorf teachers' perceptions of parental input into the curriculum. Waldorf holds the realm of curriculum sacred to its faculty. Parental involvement in this realm is generally unwelcome and discouraged; indeed, some Waldorf teachers told us that they would have to ask parents to leave the school if they interfered in the curriculum because it would undermine the primary strength of Waldorf pedagogy. A large number of parental concerns expressed on the Waldorf critics list (PLANS, 2003) address this very issue. While some have defended it as a necessary component to maintain the integrity and strength of Waldorf pedagogy, others have argued that it demeans the integrity, evokes a veil of secrecy, and perpetuates a milieu of mediocrity by allowing teachers to proceed under of cloud of misguided conceptual understandings and unchecked philosophical underpinnings. Waldorf teachers have countered that no veil exists, just a protection of the realm of the teacher's role to be an artist in the classroom. And, in fact, Waldorf teachers argue that they hold regular open houses, parent nights and/or conduct other venues of communication so parents will know exactly what is going on, and why. So why does the rift persist? This study has not satisfied the answer to that question, though we certainly believe it is worthy of further investigation because it appears be a major contributing factor to the challenge of bringing Waldorf science education into open dialogue with the science education community.

Teacher perspectives. The primary means to get at an answer to this research question was derived from the Waldorf teacher interviews and surveys (see Figure 5 through Figure 8 and Table 8 through Table 12). Almost 98 % of the teachers surveyed (176) agreed that the teaching of the science processes is important and an equal percentage agreed on the importance of teaching science concepts. The only significant deviation from these numbers is in the category of the teachers with 2-3 years of experience where 82 % stressed the importance of science concepts. What is overwhelmingly clear is that science *topics* go hand in hand with the learning of science *methods* although, as it has been expressed in the narrative data, the *method* referred to is primarily *phenomenological* (observation of phenomena).

When it comes to the application of this method (i.e., question #3: *I know what it takes to teach science*), the distribution along the years is certainly not as even. Fresh from their training the first year teachers appear quite confident about their science teaching capacity (89 %). This is already less so during their second year (83%). From year 3-5, there is a definite reassessment of that capacity (70 % in year 3, 75 % in year 4 and down again to 70 % in year 5). There is then a reversal of the trend as teaching skills are consolidated and better integrated: 88 % of teachers with 6-10 years of experience and 95 % of those with 10-15 years of experience claim that they know what *science teaching* is all about. The next group (16-20 years) however expresses a dramatic shift as only 46 % of the teachers surveyed had the same claim. Is this the sign of a crisis in personal confidence, of an acute awareness of all that it takes to truly satisfy such an approach to teaching science as someone becomes more wise and humble the more professional experience one gets? Is 46 % a sign of wisdom or disillusionment?

It is interesting to note that only 61 % of the same teacher group (16-20) is not afraid of being asked questions they can't answer (Q# 8) slightly above the year 1 group (60%) and year 2-3 respondents (58%). This is a sharp contrast from the 82 % of year 3-4, 76 % of year 1-2, 75 % of year 4-5, 72 % of years 6-10 and 68 % of years 11-15. Do teachers of this age group whose generational background is so different then theirs, that they feel they can't quite meet them? Despite these "fears", this group of teachers claims that they have a good grasp of science ideas (100%), that they understand the relationship between phenomena and concept (100%), that their students enjoy science and are getting what they need (100%) and they practice realistic assessments (90%).

In the area of understanding science ideas 100% of the 16 to 20 group expressed high levels of confidence. The next highest was the 6-10 group (94%). The lowest group was year 3-4 (61%); the year 4-5 group was 66%. Year 1 teachers showed the lowest score (62%) on the topic of administering realistic assessments to determine student learning, followed by the year 3-4 group and 4-5 group (66%). However, 100% o the year 3-4 and 4-5 groups expressed high confidence in presenting relationships between phenomena and concepts to students (Q# 10). This situation may orient therefore the questioning about the relation between grasping science ideas and administering proper assessments quite independently from the capacity of relating concept and phenomena. As these two are so fundamentally characteristic of the Waldorf approach to science teaching described as phenomenological one then wonders about the necessity of expanding the understanding beyond the approach itself and into the realm of science ideas if one is striving toward realistic assessment of students' science learning.

The capacity of relating phenomena and concepts in an understandable manner (Q# 10) is one that is shared by most groups at a very high level (97%). Year 1 teachers are the lowest group but at 81 % they nevertheless still rate themselves quite high in that category. After a dip in year 2-3 (85%), all other groups is showing a perfect score (100%) with exception of year 6-10 at 96%.

There is also an overwhelming sense (93%) that Waldorf students mostly enjoy their science classes and get what they need out of them (Q# 12). All the scores range between 90 % to 100 % except for year 3-4 teachers at 78%. This is the same group that scored the lowest in the grasping of science ideas (61%) and realistic assessments (66%) and the second lowest at knowing what it takes to teach science (75%). Ironically, this is the group that posted the highest score (82%) as to not being fearful of questions they can't answer. This profile of the fourth year teachers, however incomplete it might be, suggests possibly a crisis point not as much as one's confidence (Q #8) but as to one's knowledge (Q #6) and skills (Q #3) to bring about (Q #12) and assess learning (Q #13) beyond the application of the approach.

As to the assessments, 22% of question # 13 respondents felt it was somewhat inadequate. That is to say that almost one for every four teachers question their assessment approach in science although most are satisfied (93%) with what and how students are learning (Q #12). Assessing appears to improve steadily with experience as we see year 3-4 and 4-5 teachers at 66%, moving to 78% in years 6-10, 89% in years 11-15 and finally reaching 91% in years 16-20.

A final topic to consider is training. Of all respondents to the question of the appropriateness of their training (Q #5), only 50% consider that they received a proper Waldorf science training. This means that every student-teacher out of two *has not* received adequate preparation. This gives the measure as to how much teachers, as suggested in the narrative data, have to compensate from this lack of training with study, preparation and consultation in order to get to the following figures: 88% know what it takes to teach science, 87% have a good grasp of science ideas, 97% have a good ability to relate phenomena and concept and 93% have their students enjoy their learning and get what they need.

The narrative data further suggest that Waldorf teachers favor a twofold strategy: a focus on observation of phenomena in order to develop a deeper awareness and relationship to nature as to how the natural world presents itself to consciousness and a heuristic mode to uncover concepts that explain phenomena. It is believed that students greatly benefit by discovering for themselves those emerging and underlying concepts provided the proper conditions prevail. The narratives do not offer enough data to assess the scope and limits of this twofold strategy although it clearly stresses the necessity of unfolding in a developmentally appropriate manner.

The context for implementing Waldorf strategies (e.g., physical resources, space, proper equipment) is characterized, to a large extent, as poor. Further, the narrative data suggest that adequate guidance from curriculum materials and other pedagogical resources, including mentoring and peer help, is also poor. This is exacerbated more because teachers, in most cases, feel that they received inadequate training regarding the Waldorf way of approaching science. As to those who a received a classical science training, they have to question a fair amount of their underlying assumptions. In spite of these conditions the majority of Waldorf teachers still expressed a self reliant spirit that believes it can hit the mark by indulging enough in study, preparation and consulting.

Certain implications for the Waldorf science curriculum and professional development have emerged relative to this research question of student, parent, and teacher perspectives: most notably:

1. There is a sense that student understanding of science is highly dependant on the teacher's own understanding which is gained through extensive study and/or preparation to penetrate the relationship between concept and phenomena, furthermore between understanding itself and observation of phenomena as they are striving to picture imaginatively the topics at hand.
2. There is a need to reexamine all aspects of teacher preparation and teacher support after Waldorf teachers begin their career. This issue involve the way student teachers receive their science training, the specialized workshops needed for professional development, the mentoring aspect and the pedagogical support literature that furthers the Waldorf curriculum indications. This also speaks to the teacher's own study and preparation.
3. The necessity to deepen and expand teachers' understanding and skills about a phenomenological approach to science learning in the context of child development. Also to articulate the epistemology around terms like imagination, observation, and understanding as well as providing tips to grasp the wholeness of the curriculum and its application.

4. The necessity to place the overall picture of Waldorf curriculum development in the context of mainstream science and to ponder the issues that are similar and different at the levels of principles, methods and assessment.
5. The necessity to face the lack of proper facilities and insufficient equipment and supplies as well as the lack of guidelines as to their use. There is also the question of the tremendous preparation time needed for science teaching
6. The necessity to address the role of the arts in teaching science; i.e., though arts are considered pivotal to Waldorf pedagogy the role they play in actually teaching science understanding is far from clear.
7. The necessity of coming to clear and attainable curriculum expectations as well the proper use of hands-on experiences in teaching and training, modeled lessons and the contribution of expert teachers.
8. The necessity to improve parents understanding of the Waldorf science approach perhaps in the context of the greater science views commonly held.

How do Waldorf Students' Scientific Reasoning and Problem Solving Skills Compare to Those of Their Counterparts in Mainstream Educational Settings?

Based on the mean performance on verbal logical reasoning task (Table 16) Waldorf students scored slightly below public school student (5.90 versus 6.15) on syllogistic reasoning and slightly higher on inferential reasoning (6.15 versus 5.72), for an overall effect of just slightly higher than public school students (12.55 versus 12.31). The data in Table 18 through Table 21break these statistics down by t-test scores for within group and between group comparisons of syllogisms and inferences, again supporting the conclusion that Waldorf students scored slightly higher than public school students; but the difference is negligible enough to conclude that there is statistically no difference between the two groups. What this suggests is that Waldorf students' ability to apply deductive logic , which involves the combination of existing information by following specific mental operations (e.g., "all A are B; all B are C; therefore all A are C"), is on par with public school students, but not significantly better.

Mean performances for non-verbal logical reasoning tasks were again slightly higher for Waldorf students at 6.90 versus 6.35 (see Table 22). The most compelling data for non-verbal logical reasoning, however, is found in Table 23, which reveal that Waldorf students prefer the "Part-First" strategy (60%)as opposed to public school students who preferred the "Whole-First" strategy (42%). Additional evidence that Waldorf students are better able to discern part-whole relations is found in Table 24, where an item analysis of responses to the TONI tasks revealed that Waldorf students outperformed public school students in all questions representing part-whole relations. In light of the *relevant literature* discussion of part-whole relations and the Waldorf emphasis on "Whole to Part" methodology, the data suggest that perhaps because Waldorf students have been extensively exposed to the "Whole-Part" relationship throughout their early educational years that they have passed through this developmental phase sooner than their public school counterparts; that is, they are actually able to discern smaller parts of the larger configuration more effectively than their 4th, 6th or 8th grade counterparts. If additional studies bear out that Waldorf students are indeed able to discern parts at an earlier age compared to public schools then a logical hypothesis would be that the perceptual functioning of Waldorf students advances at a more rapid rate than that of public school students; in short, that Waldorf students are equipped with a more sophisticated form of non-verbal logical reasoning at an earlier age. There should be no rush to conclusions, however -- this study randomly selected the responses of 40 Waldorf students and compared them to 40 public school students. More studies with larger numbers of subjects are needed.

In terms of the TIMSS tasks, the evidence summarized in Table 25 indicates that 4th grade Waldorf students scored about the same as the United States and International average (81% vs. 82% and 80% respectively); and outperformed U.S. and International 4th grade averages for providing a correct description and interpretation of the solution (73% vs. 65% and 64% respectively). Waldorf 8th grade students outperformed U.S. students and international students in the category of correct answers (98% vs. 90% and 92%) and in providing a correct description and interpretation of the solution (98% vs. 81% and 88%). Figure 10 and figure 11 provide graphic comparisons of these scores. Caution in making quick conclusions is once again encouraged, however. First, the total number of Waldorf students assessed was about 10% of the number of U.S. students, and 1% of the total international number assessed. Second, the magnet task is one task in a battery of 5 science (and 1 of 13 math and/or science) performance tasks administered in the full TIMSS study. TIMSS also used another battery of tests to assess student content knowledge, which the Waldorf study did not do. This is not to say that the Waldorf numbers are not significant – they are – all the more so because the TIMSS magnet task was carefully replicated to maintain validity and reliability; but it is important to compare like findings, which is the magnet task only. How Waldorf students would compare if the full TIMSS batteries of performance and content assessments would be a matter of conjecture.

The data suggest other factors beyond group comparisons, however. The sample student narrative responses in Table 26 provide examples of student written responses to the magnet task (original student papers with drawings and illustrations are available in the full data set; excluded here for space reasons). In our data analysis we looked at both the original written responses and think-aloud strategies the students used to solve the magnet tasks. In particular, we wanted to see how well students could *analyze, compare, infer*, and *evaluate*; which are indicators of higher-order scientific reasoning skills. We found that the majority of students at the 4th, 6th and 8th grade level could effectively identify the necessary components of the magnet task process (which is characteristic of *analysis*). The majority of students in all 3 grade levels also demonstrated strong abilities to compare properties of the magnet task objects, and could break down the necessary components of the processes to solve the problem (*compare)*. Most 6th and 8th grade students also drew conclusions, made predictions and posed evidence-based hypotheses and explanations; and approximately half of the 4th grade students drew evidence-based conclusions (*infer*). This quality of higher-order reasoning is generally expected at the 6th, and certainly the 8th grade level, but our researchers were surprised by the large number of 4th grade students able to provide the level of sophisticated inferences. No comparison group was used to conclude that Waldorf 4th grade students inferred at a higher level than their public school counterparts, though the observations that this appeared to be the case is reason to suggest that further studies comparing inferential reasoning would be justified. Finally, we found that over 90% of 8th grade students and approximately 70%of the 6th grade students evaluated the soundness of their procedures beyond the simple task at hand; i.e., they provided enough descriptive explanations to their conclusions to make them credible and significant (*evaluate)*. The conclusion is that, at least in reference to the magnet task, Waldorf demonstrated a high level of higher-order scientific reasoning skills.

The overall effect of all 3 tasks (non-verbal logical reasoning, verbal logical reasoning, and magnets) leads to a tentative conclusion that Waldorf students scientific reasoning and problem solving skills appear to be at or slightly above those of their counterparts in mainstream educational settings. A more extensive investigation, with large numbers and a control group, is encouraged.

Does Waldorf Offer a Viable Form of Science Education?

The most difficult question to answer was saved for last, for while it is possible to draw conclusions based on data we have analyzed and discussed up to this point, it will not quite satisfy the complexity of this question. Waldorf does not, for example, fully align itself with the national science standards, though as the reviewers point out, there are numerous favorable processes that support science as inquiry, so they gave *pedagogical appropriateness* and *science content* fairly high ratings, overall. On the other hand, some of the concerns the reviewers raised about questionable concepts would be reason enough for some critics to discredit Waldorf science education all together. The evolutionary notion that animals are the by-products of human development, that the spirit of man physically incarnated into soul qualities that manifested themselves into various animal forms, is highly suspect as a valid scientific theory. So is the geological position that earth evolved through Lemurian and Atlantean epochs and is now in its fifth post-Atlantean epoch. Or the theory that the 4 kingdoms of nature are mineral, plant, animal and man. Of course, "mainstream" science textbooks are also "riddled with errors". Take, for example, the recent study of 12 popular science textbooks which found 500 pages of errors (Associated Press, 2001). "These are terrible books, and they're probably a strong component of why we do so poorly in science," said John Hubisc, the North Carolina State University physics professor who conducted the 2 year survey. This, of course, does not condone Waldorf's conceptual inaccuracies, but it underscores that if inaccuracies are the litmus test for disqualifying a particular curriculum then approximately 85% of middle school science textbooks used in the United States must be eliminated (Associated Press, 2001). However, a line can be drawn between conceptual inaccuracies that are subject to correction and pseudoscientific explanations that have no empirical grounding, and since some of Waldorf's concepts fit into the latter category we will revisit this distinction shortly.

Giving Waldorf science education the benefit of the doubt for the time being, what about its actual methods of instruction? The analysis of the videotaped lessons did not raise any blatant red flags. Waldorf seems a bit heavy on "demonstration", perhaps didactic in that it has carefully selected the content it wishes to teach and disallowed other content, but if this disqualifies Waldorf science as a viable form then so must much of "mainstream" science education be disqualified, for research shows that for all the positive rhetoric of the National Science Education Standards they have yet to make an impact in actual classroom instruction. Science instruction runs along a continuum from highly structured direct instruction to open ended "discovery" learning; Waldorf falls between these two extremes – a little closer to the direct instruction side, but with a decidedly different focus in that, unlike many direct instruction approaches, Waldorf chooses to delve more deeply into a handful of ideas versus extensive coverage. In this sense Waldorf actually comes closer to the kind of delivery model supported by the TIMSS findings and AAAS Project 2061 (Nelson, 2001; Stigler & Hiebert, 1999), i.e., less is more. Defining what "less" means is of paramount important, however. Research overwhelmingly supports the position that content specific strategies render the greatest results (National Research Council, 2000). Research also shows that misconceptions are difficult to break (as exemplified in the classic video study of Harvard and Massachusetts Institute of Technology (MIT) graduates unable to light a bulb using a wire and battery (Private Universe Project, 1989)), thus conceptually correct content is equally critical. For Waldorf to answer that it provides a viable form of science education it must provide a solid rationale for it's selection of "less" and "correctness". At this point some of its selections are dubious, but once again we will give it the benefit of the doubt that once scientific soundness is addressed Waldorf will be willing to remove and replace erroneous information.

But will Waldorf be willing to remove and replace erroneous information? Does it believe it has erroneous information? Not according to the survey results – thus complicating the viability of Waldorf science education question even more. For how will Waldorf make changes if the majority of its teachers believe they know what it takes to teach science, that they have a good grasp of science ideas, and are confident presenting phenomena and concepts to their students? The statistical evidence suggests three possibilities: (1) that the Waldorf teachers surveyed are overly confident in what they know; (2) that they're not really sure what they are claiming high confidence to; or (3) that they really know a lot. The narrative data and interviews provided a slightly different picture, however, dispelling the last option -- most said they did not know a lot; in fact, many said they knew virtually nothing until it was time to teach the topic, then they gathered enough information to at least stay ahead of the students. The first option -- that Waldorf teachers were overly confident in what they knew is also not supported by the narrative evidence. Though it is true that some Waldorf teachers demonstrated a high degree of scientific understanding and others a high degree of “Waldorf-specific” concepts (e.g., Steiner’s view of evolution), the majority actually appeared to be struggling with the question about what should be taught and how it should be taught. There was struggle over whether Rudolf Steiner’s teachings about science had any place in the curriculum, or if content to be delivered should be drawn from more mainstream sources. In actuality, the majority of Waldorf teachers we interviewed pointed to this latter choice as the more ideal; albeit they were uncertain about how to go about doing this. A resounding plea for assistance in this area was expressed. This is also evident in the relatively low ratings Waldorf teachers gave to their teacher preparation for science methods. Waldorf teacher educators claim to be responding to this need, but if Waldorf is to enter into the “viability of mainstream science education” one has to ask if traditional Waldorf teacher preparation is going to do it. The less experienced Waldorf teachers tend to be intimidated or swayed by the dictates of the more experienced to "teach Waldorf science this way". The more experienced tend to either expect the less experienced to get it together and follow in the footsteps of the wise, or they acknowledge that they've really only been winging it themselves all these years, and they wished there was more guidance. This need for more guidance, resources, connection with other perspectives, etc. rings throughout the movement -- suggesting the possibility for reform, albeit an uphill battle because of the adherence to the belief that much of what others say students should be taught is "not developmentally appropriate".

This raises one additional teacher perspective that heavily influences the “viability” question: many of the Waldorf teachers we surveyed and interviewed hold a strong bias that public school science education is inferior –void of imagination and inspiration where students are taught “dead” concepts through rote memorization, where the fostering of human capacities through integration of “the head, heart and hands” is absent. In several instances the justification for Waldorf education seems to be a diatribe against public schooling and the science education research community. Virtually no Waldorf educators we surveyed or interviewed kept abreast of current trends and research is science education. It is difficult to bring Waldorf to the table of science education discourse unless they step up and take their place.

When looking at Waldorf student performance it is understandable why it would be difficult to dismiss Waldorf science education as a viable method. Certainly based on the tasks administered in this study students performed impressively, demonstrating high levels of nonverbal and verbal logical reasoning, higher order scientific reasoning skills, confidence and intrinsic motivation. Whether these results will sustain themselves when more comprehensive investigations are conducted, or will transfer to other cognitive domains, remains uncertain at this point, but clearly further study is justified. Waldorf students should also be assessed for their science content knowledge. The prediction is that under grade six they will not perform high, which at this point Waldorf would argue is developmentally appropriate. However, if Waldorf is to enter into science education discourse as recommended, the articulation of what Waldorf students should understand, know, and be able to do at each grade level should be at the forefront. This is going to be a challenge for many Waldorf teachers since assessment and accountability represent areas of great ambiguity. The notion of identifying outcomes and assessing whether they have been met is opposed by some, and even though the majority acknowledge that some form of assessment is necessary, the identification of what they should be looking for and what counts as evidence varies widely. A coherent assessment system is currently lacking.

CHAPTER 7

How Could Waldorf Offer a Viable Form of Science Education?

This chapter rephrases the question "Does Waldorf offer a viable form of science education" to "How *could* Waldorf offer a viable form of science education?". At the heart of this question lies a distinction between pseudoscientific and scientific thinking – a distinction made by accepting the current paradigm of what constitutes science. As Thomas Kuhn's (1962) classic theory of "paradigm shift" points out, there is an accepted "normal science" that the majority of practicing scientists adhere to, subject to shift if and when there is enough evidence and power to "overthrow" the existing paradigm. Shermer's (1997) definition of paradigm is quite helpful: "A model shared by most but not all members of a scientific community, designed to describe and interpret observed or inferred phenomena, past or present, and aimed at building a testable body of knowledge open to rejection or confirmation." What is this current paradigm? Carroll's (2002) characterization of scientific theories captures it well:
"(a) being based upon empirical observation rather than the authority of some sacred text; (b) explaining a range of empirical phenomena; (c) being empirically tested in some meaningful way, usually involving testing specific predictions deduced from the theory; (d) being confirmed rather than falsified by empirical tests or with the discovery of new facts; (e) being impersonal and therefore testable by anyone regardless of personal religious or metaphysical beliefs; (f) being dynamic and fecund, leading investigators to new knowledge and understanding of the interrelatedness of the natural world rather than being static and stagnant leading to no research or development… (g) being approached with skepticism rather than gullibility, especially regarding paranormal forces or supernatural powers, and being fallible and put forth tentatively rather than being put forth dogmatically as infallible."

Shermer (1997) offers additional clarifications of the scientific versus pseudoscientific thinking: "(h) anecdotes do not make a science; (i) scientific language does not make a science; bold statements do not make claims true; (j) the burden of proof for extraordinary claims is on the person making the claims; (k) unexplained in not inexplicable (i.e., just because it cannot be explained does not make it a true mystery of the paranormal); (l) appeal to ignorance (i.e., the fallacious argument that if you cannot disprove a claim it must be true); (m) drawing conclusions before the facts warrant it; (n) overreliance on authorities; (o) either-or fallacy (i.e., if you discredit one position, your are forced to accept the other); (p) the need for certainty, control, and simplicity; (q) ideological immunity (or, to use Jay Stuart Snelson's definition: educated, intelligent, and successful adults rarely change their most fundamental presuppositions (Snelson, 1993)".

Using these features of the scientific thinking paradigm, what *could* Waldorf do to demonstrate its viability?

Rudolf Steiner, Anthroposophy and Waldorf Education

As a first step Waldorf should disregard Rudolf Steiner and Anthroposophy as the source of accurate scientific concepts. The basis for this recommendation is that Steiner's teachings do not pass the tests of empiricism (a,b,c and d), are not testable by anyone (e), have not changed much, if any, since Steiner introduced them (f), and rely on paranormal statements that cannot be verified (g). Accepting many of Rudolf Steiner's scientific indications in light of the absence of empirical evidence violates the core premises of the scientific paradigm. The anthroposophical argument is that Rudolf Steiner applied empirical investigations in the spiritual world where he garnered higher spiritual truths, but even if this turns out to be accurate it must be discarded as scientifically valid because it cannot be replicated by anyone. If and when the scientific paradigm can ever be overturned with an anthroposophical paradigm because a preponderance of empirical evidence demands it, anthroposophists will have reason to celebrate; but there is little in the current paradigm to suggest this is likely.

There is also an argument that Anthroposophy and Waldorf Education are inseparable. If that is true then it is difficult to understand how Waldorf could offer a viable form of science education. But many educators argue that the methods of Waldorf and Anthroposophy are separable -- public Waldorf educators have gone so far as to argue this point in court when challenged on separation of church-state issues. Legal ramifications aside, there is little doubt that a distinct separation from Anthroposophy is needed. Consider the anthroposophical tenets of developmentalism and evolution. Steiner's developmentalism is based on his teachings that children pass through three 7-year stages: the first characterized by the reincarnated human spirit adjusting to the physical world; the second by the incarnation of the "etheric" body with the physical body; and the third by the incarnation of the "astral" body. Steiner's evolutionary teachings suggest that throughout these developmental phases the human being is actually recapitulating evolutionary phases from previous epochs, dating back to pre-earth existence when the human spirit resided on ancient Saturn, Sun and the Moon. To Waldorf's credit there is no evidence that such ideas are taught to the children. There is evidence, however, that the rationale for the structure of the Waldorf curriculum is to properly guide the incarnating human spirit through these developmental and evolutionary phases; and that anthroposophical Waldorf teachers adhere to this rationale as a basis for why and what they teach.

Bringing Waldorf into a Secular Environment

By removing Anthroposophy the arguments of Waldorf's questionable philosophical foundation are removed and Waldorf can focus, instead, on the strengths of its methodology and ways to improve it. It should be noted, however, that rejecting Steiner and Anthroposophy as the source of accurate scientific concepts does not signify the rejection of the many exemplary Waldorf methods that have attracted the attention of innumerable parents, educators and academics. We concur, here, with a position expressed by Waldorf critics Dan Dugan and Judy Daar (1994): "It might be possible to establish schools that take many of the good Waldorf school ideas into a secular environment, but this could only be done by people not indoctrinated by Anthroposophical training." Now the question is what are those good ideas and how could they be brought into a secular environment?

One of the more intelligent overviews of Waldorf science education (partly because it does so without explicit spiritual references) can be found in Brien Masters' article "Science in Waldorf Education – General Survey" (Masters, 1992). In that article Masters first describes how kindergarten and the first five grades lay the necessary foundation for effectively approaching science, which broadly speaking concerns itself with the material world: "…we see that in the natural course of the school curriculum, the child before the age of 11/12 years undergoes a sequence of different relationships to this material world. The way these relationships are taken into account in education forms an integral part of any educational science program (p.7)." He argues that "…keeping to the phenomena preserves the freedom of the student to make his-her own deductions without recourse to existing theories….The emphasis is not on knowledge with labels attached…. The emphasis is on joy of discovery, beauty of form, play of light on color, love of the world and all that therein is."

Masters goes on to describe Waldorf science in the early grades, where the child learns science through nature stories, leading toward the study of natural science in grade 4. He discusses the grade 4 emphasis on the *form*, *habitat and movement* in animals, and the grade 5 emphasis on plants, and particularly emphasizes the importance of accurate observation and/or use "inner power of visualization" to learn about creatures or plants where first-hand observations are not likely. Masters argues that the Waldorf methods of the first five grades "…present the students with images of their own nature at physiological and psychological levels appropriate to their age and understanding" (p.12) and prepare them for the intellectually-based study of cause and effect in sixth grade. "To understand science and scientific law, the human being needs to be able to apply that form of intelligence which can grasp the logical connection between cause and effect. With this type of intelligence the world is reduced, as it were, to that which is purely material" (p.12). He discusses how specific training of the senses is given to "… heighten the act of perception (e.g., perspective drawing and shadow drawing) so that "… the scientific law living within the phenomena can be 'discovered' by the pupils…. To do this, observation is not enough. Now they will need to apply their sharpening power of intellect. Awakened observation must now be penetrated by equally awakening causal thinking. Only then will the mind *reach* the 'laws' (p.13)…. Thus, from day one, a certain mode of scientific training is established. Scientific law arises from, and the understanding of it is stimulated by, observable reality. In later years there will be time and occasion for entering into hypotheses."

Masters continues with a discussion of the physics curriculum of grades 6, 7 and 8 as it spirals through *sound, light, color, heat, magnetism, and electricity*; "…connected closely with the developmental stage that the pupils are going through …" In grade 7 Astronomy and Chemistry are also introduced, and in eighth grade anatomy --three subjects that further stimulate the powers of abstract thinking. "Because the natural laws that operate in the realm of chemistry are more elusive than those discussed in connection with physics, it will be necessary for the chemistry teacher from the outset to stimulate the students' imagination for what is hardly visible: the inner processes at work." (p.18)

Any curriculum and methodology are subject to scrutiny and disagreement, Masters' "Waldorf Science Survey" included, but his survey was included here to illustrate that, indeed, Waldorf does possess some "good ideas" that are transferable to the secular world. To answer the question of how to do this is more complicated but could conceivably begin with a scrutiny of Masters' survey and the Waldorf science curriculum outlined in this study. It would also be a good idea to identify Waldorf curriculum materials with prevailing inaccuracies and pseudoscientific explanations and remove them from consideration. Unfortunately, this probably means that the majority of Waldorf science curriculum materials are subject to removal or at the very least, extensive refinement. Wilkinson's Waldorf Curriculum Series (Wilkinson, 1975,1978,1982), for example, is so filled with pseudoscientific explanations (e.g., "Before the world came into being materially…there was a 'watery' state; before that an 'airy-gaseous'; and before that something akin to 'warmth'…. Into the original 'warmth' element the gods poured something of their own substance, thus forming the basis of what later became the human physical body") that it would really be best to disregard the booklets altogether. von Mackensen's 3 volume series, *A Phenomena-Based Physics* (von Mackensen, 1992)advocates an alternative, "phenomenological" approach to science because of the need to "…activate our soul-spiritual forces." Von Mackensen discredits the traditional science paradigm in lieu of a "goethenistic" phenomenological approach, even in light of "external provability" difficulties. Perhaps if one wanted to wrestle with von Mackensen's largely philosophical tone these book's could be useful but we found the wording difficult to follow. Though the author walks through the grade 6 to grade 8 physics curriculum and provides descriptions of various science activities, it is not very teacher-friendly and too many concepts are inaccurately stated. In *Sensible Physics Teaching* (D'Aleo & Edelglass, 1999) D'Aleo and Edelglass took much of what von Mackensen said and made it more reader friendly. The same "sense-based" arguments that von Mackensen makes are made here as well, and so are many of the conceptual errors. Still, while the book is limited in its value as a comprehensive methods text and would need to be revised with content corrections, it is worth reading because it describes Waldorf physics activities in a straightforward, easy to follow manner. Further, corresponding Waldorf science kits have been developed.

Trostli's *Physics is Fun* (Trostli, 1995) is the most comprehensive Waldorf physics resource we identified, and is recommended for several reasons. First, the concepts, though minimally covered, are accurate. Second, ample activities are logically organized around thematic units. Third, these activities are thoroughly described and illustrated so that teachers should be able to organize and teach entire physics units. Fourth, the book is true to both Waldorf methodology and generally accepted standards for physical science education. The introductory section still raises some questions because it relies on Steiner's claimed insights into the unseen world, but because Trostli gets beyond this and substantively presents the methodology through his own lens the general impression is that this is one of the few Waldorf resources worth holding onto.

In the area of astronomy we found 2 excellent Waldorf resources, *Sky Phenomena* (Davidson, 1993) and *Astronomy: An introduction* (von Baravalle, 1991, 2000). Author Norman Davidson's obvious passion for accurate observations of the sky and avoidance of specific pedagogy makes both of these books (he liberally edited von Baravalle's book) readable, helpful guides. As Davidson says in the introduction to his book, "But, as far as the classroom is concerned, no book can be a substitute for the enthusiasm and imagination of the teacher inspiring students to enter the subject fully (p. xii)." Davidson helps to inspire enthusiasm and imagination in these 2 books. The down side, however, is that because pedagogy is not the focus there is less certainty about how this material could be translated into teaching methods. There are two Davidson articles in *Waldorf Curriculum Studies: Science in Education* (Masters, 1992) that address pedagogy, but not to the extent needed to put together whole units of study. Thus Waldorf must either fall back on Rudolf Steiner's indications for teaching astronomy, or Roy Wilkinson's; but both of these are intermixed with anthroposophy.

We also found *The Living World of the Plants: A book for Children and Students of Nature* (Grohmann, 1999) to be influenced by anthroposophical ideas, but because the author wrote this as a story to children, the anthroposophy is not overt and, because this book provides numerous accurate botanical descriptions, along with clear illustrations and methods to engage students imaginatively in the learning of this topic, it should not be discarded as a potentially valuable resource. As with astronomy, we found a few related articles in the Master's (1992) collection of Waldorf science education articles on botany, but again, not substantive enough to ascertain how entire botany units could be put together.

Since this is not meant to be an exhaustive examination of Waldorf's science resources, but rather consideration of what it would mean to secularize Waldorf science education (i.e., to make it viable in the eyes of the scientific community), we feel it is clear that a fair amount of resource scrutiny and refinement will be necessary. The bottom line is that, in our examination of Waldorf science education resources, we found that while there are many sound scientific ideas with exemplary methods, Rudolf

Steiner's pseudoscientific ideology must be extracted before the work can partake in the 21st century science paradigm.

Is Anything Else Needed?

Yes. Waldorf needs to come to terms with the five defining theories of modern scientific thought (Wynn & Wiggins, 1997) -- the five "Big Ideas" of Physics, Chemistry, Astronomy, Geology, and Biology. A "Big Idea", according to Wiggins (2001), has: lasting value; can transfer to other inquiries; serves as a "key concept for making important facts, skills, and actions more connected"; summarizes "key findings/expert insights in a subject or discipline"; and requires "uncoverage" (i.e., It has many layers and nuances that are not obvious to the naïve or inexperienced person and is often misunderstood and prone to disagreement. Therefore one must dig well beyond the surface to grasp it, and in so doing begin to gain a "depth and breadth of insights into the subject"). A brief discussion of the 5 "Big Ideas" in science follows, not because we are suggesting that Waldorf students must receive direct instruction in them but rather because well prepared teachers of science need to have reasonable understandings of these Big Ideas if they are to make rational decisions about which way to go with science education.

First among the "Big Ideas" is Physics' theory of the atom – the basic building blocks of the universe. Waldorf literature appears to avoid this theory almost entirely because atoms are not directly observable and because they are "…merely models (imaginations) that constitute an intermediate virtual concept that is constructed mentally in order to 'explain'…" (D'Aleo & Edelglass, 1999). While it is true that scientific models exist to interpret and understand atoms, the experimental evidence emerging from those models overwhelmingly supports the hypothesis that atomic structures exist and are not "imaginations". Modern day understanding of the atom is the result of an ongoing refinement of scientific models, and it would behoove the science educator to have a sense of these models and how they have advanced scientific understanding. Aristotle proposed the first model, that matter could be subdivided indefinitely, with no ultimate underlying structure, or building blocks. The Democritus Model challenged Aristotle and argued that there is an underlying structure of matter – a small unit that could not be cut (*a tomos* is Greek for "not cuttable"). Dalton's Billiard Balls model provided experimental evidence for the Democritus model by picturing atoms as miniature billiard balls, and he provided evidence of constant composition of the elements that make up these "billiard balls." Thomson's Plum Pudding model used gas discharge tubes to calculate the mass of moving, negatively charged particles (electrons), and through a series of experiments concluded that all materials contain electrons – small subdivisions of matter, and that positively charged protons exist with the atom to counterbalance the negative electrons. The Plum Pudding model disproved Democritus's hypothesis that atoms are indivisible. Rutherford's Solar System model used positively charged alpha particles to hypothesize that atoms contain a positively charged central nucleus with electrons orbiting around it, like planets orbiting the sun. Bohr's Model improved upon Rutherford's by hypothesizing that electrons have certain "allowed" orbits, like being transported by an elevator -- it's okay to get out at each floor, but not in-between floors. The Quantum Mechanics model replaced Bohr's hypothesis by mathematically describing the properties of electrons as waves or undulations rather than particles, effectively replacing Bohr's specific locations of electrons with probabilities of electron locations. The Quark model now suggests that even smaller particles than electrons exist. Clearly there is room for more discovery, but it is equally clear that ignoring the existence of atoms is to ignore more than 2,000 years of theory development on the topic.

The second "Big Idea" concerns the properties of these atoms, chemistry's Periodic Law. While Waldorf does an excellent job introducing chemistry experientially, it largely avoids a consideration of the relationships among different kinds of atoms until high school. Waldorf educator Fritz Julius (2000) argues that it is "…difficult to build up a living image of the world for the students if we use this system as the starting point (p. 100)", an understandable position since the Periodic Table was taught as (and remains) an abstraction to so many of us. In reality, however, chemistry's long journey to sort the elements and logically organize them to predict and explain phenomena can be a fascinating study that engages the imagination and stimulates understanding. Julius also criticizes attempts to make it more interesting and understandable as "…a symptom of the tendency of modern people to permit the wholeness of the world to be dissected into isolated pieces (p. 101)", though concedes that other approaches are possible and that the periodic system should be studied, just not as a starting point. Pedagogically, this makes good sense and we do not dispute Julius' position. The concern is whether Waldorf, as a whole, does indeed give this theory due consideration or relegate it to a status of moderate importance.

The third "Big Idea" concerns the question of where all these atoms came from, astronomy's Big Bang Theory. From Davidson's revised edit of *Astronomy: An Introduction* (von Baravalle, 1991, 2000), it is clear that the early emphasis on astronomy is to "… show the stars as people can really experience them…. Once the student confronts the actual astronomical phenomena in the heavens, a safe basis is established on which different views and conclusions can come together in the understanding. By developing his or her own powers for observing and thinking about the stars, the student has opened up inwardly and has increased the strength for penetrating the realities of the worlds around (p. vii)." If "penetrating the realities" includes "penetrating the Big Bang Theory" then Waldorf's approach to astronomy is really quite educationally sound; in fact, it is a step above many mainstream approaches that de-emphasize direct observational experience and prematurely delve into abstract theories. On the other hand, if Waldorf chooses to avoid this theory in lieu of alternative explanations then it ignores a theory that, since Hubble's discovery in 1923 of another galaxy outside of our own, has substantiated the existence of billions of expanding galaxies which, if ,mathematically calculated in reverse, would theoretically meet at "zero-time", the "Big Bang", some 15 billion years ago.

The fourth "Big Idea" considers how the matter of the universe arranged itself in planet earth, geology's theory of Plate Tectonics. We have found little in the Waldorf literature or teaching that incorporate a consideration of the multiple geological observations that ultimately (in 1965) resulted in the hypothesis that plate movement explains the phenomenon of continental drift, which in turn explains the model of a supercontinent called *Pangea*. Perhaps this is because Waldorf's attention to phenomenological experience limits the educational experience to what students can observe and touch; but to use Waldorf's own pedagogical explanation, phenomenological experiences must be penetrated with inner thought. However that inner thought emerges -- through student questions about earthquakes and volcanoes, about what the earth looked like thousands of years ago, about what goes on under the earth's mantle, about fossils – it seems this theory should have a place in the Waldorf science curriculum, or at the very least, Waldorf teachers should be aware of the theory so they can make a logical decision as to when and how this could fit into the study of geology. Kolisko (1945,1978) discusses Wegener's theory of *Continental Drift* in the Waldorf booklet *Geology*, but he does so in the context of arguing for the existence of the ancient continent of Atlantis, which split, then sank down into the "flood". "If we imagine also that a continent splits in the middle, and moves, it is no longer astonishing that the coast lines fit into each other. The continent splits, the flood breaks in, and because the continents are movable, displacements happen. Wegener's theory of the Continental Drift, brought into connection with all the facts mentioned before, leads immediately to the conception that there must have been an Atlantic Continent (p. 32)". Kolisko's argument predates the geological evidence leading to Plate Tectonics, but now that that evidence is available we encourage Waldorf educators to examine it. Recency of available evidence continually makes it possible for science to refine or even completely throw out its earlier theories that lacked the necessary evidence.

The fifth "Big Idea" looks at the question of how life on earth originated and developed, biology's theory of evolution. This is hardly the place to enter into a lengthy discussion of the scientific community's theory of evolution compared to anthroposophy's theory, but it is the place to acknowledge that evolutionary theory, outlined by Charles Darwin in his 1859 *On the Origin of species by Means of Natural Selection*, has received widespread acceptance among the scientific community because, after decades of analysis and scrutiny, the theory continues to meets the rigorous methodological requirements that justify its inferences to explain observed phenomena. Shermer (1997) summarizes the theory as follows:

> *Evolution:* Organisms change through time. Both the fossil record and nature today make this obvious.

Decent with modification: Evolution proceeds via branching through common descent. Offspring are similar to but not exact replicas of their parents. This produces the necessary variation to allow for adaptation to an ever-changing environment.

Gradualism: Change is slow, steady, stately. *Natura non facit saltum* – Nature does not make leaps. Given enough time, evolution accounts for species change.

Multiplication of speciation: Evolution does not just produce new species; it produces an increasing number of new species.

Natural selection: The mechanism of evolutionary change operates as follows:

A. Populations tend to increase indefinitely in a geometric ratio: 2,4,8,16,32,64,128,…
B. In a natural environment, however, population numbers stabilize at a certain level.
C. Therefore, there must be a "struggle for existence" because not all of the organism produced can survive.
D. There is variation in every species.
E. In the struggle for existence, those individuals with variations that are better adapted to the environment leave behind more offspring than individuals that are less well adapted. This is known as *differential reproductive success*.

Conclusion

Once again we return to the question: *How **Could** Waldorf Offer a Viable Form of Science Education?* We believe we have answered it by pointing to a rigorous processes that distinguishes pseudoscience from science --with a rejection of pseudoscientific ideas, however pivotal they may have been to Waldorf science education in the past. This includes removal of Rudolf Steiner and anthroposophy as sources of accurate scientific concepts, a separation of Waldorf science education from anthroposophy, specific attention to bringing the "good ideas" of Waldorf into a secular environment, a critical review Waldorf science resource materials, and expungement of materials that don't make the grade. We then pointed to the five "big ideas" that Waldorf needs to come to terms with: (1) physic's model of the Atom; (2) chemistry's theory of Periodic Law; (3) astronomy's "Big Bang" theory; (4) geology's "Plate Tectonics" theory; and (5) biology's theory of "Evolution".

Is it worth the trouble? Is it realistic to assume that the "good ideas" of Waldorf could be extracted from the pseudoscientific ones and emerge a strong and vibrant (and viable) form of science education? The evidence from this study indicates that Waldorf will have its work cut out and will have to lose some ideas and people (some anthroposophists are not going to accept the changes that have to be made) along the way, but Waldorf's rich array of creative methods that stimulate imaginative thought and engage students in potentially meaningful activities could undoubtedly enrich secular education.

Ultimately, our case for encouraging the effort comes anecdotally and is about the students. Time and again as our researchers visited the many Waldorf schools across America we were impressed with the eager, confident and curious Waldorf students we encountered. These students demonstrated original thinking and innovative problem solving, leaving us with the impression that they cared about what they were doing, were intrigued by challenging situations, and penetrated matters with an artist's perception. One can only imagine how far they could go with sound scientific ideas as part of their repertoire. We think it is worth finding out.

References

Abell, S. K. (1989). *The effect of a problem solving inservice program on the classroom behaviors and attitudes of middle school science teachers.* Paper presented at the National Association of Research in Science Teaching, San Francisco.

Allen, R., Klingsportn, M. J., & Christensen, M. (1980). Student attitudes toward instructional variables in a human anatomy class as assessed by a projective technique. *Journal of Research in Science Teaching, 17*(5), 463-468.

American Association for the Advancement of Science. (1993). *2061 Benchmarks for Science Literacy*. New York: Oxford University Press.

Associated Press. (2001, January 16). Science textbooks riddled with errors. *San Francisco Chronicle,* pp. A4.

Baravalle, H. V. (1974). *Astronomy: An introduction*. Spring Valley: St. George Book Service.

Barnes, D. (1976). *From communication to curriculum*. Harmondsworth, England: Penguin.

Barnes, M. B., & Barnes, L. W. (1989). *Observations related to teacher concept formation in an in-service setting emphasizing question-asking behavior.* Paper presented at the National Association for Research in Science Teaching, San Francisco.

Bojarsky, M. (1999). *A demonstration manual for use in the Waldorf School 8th grade chemistry main lesson*. Orangevale: Bojarsky, Mikkio.

Bonhiver, G. (2002). *Education expert softens support of Waldorf.* Available: http://www.waldorfcritics.org/index.html#Gardner.Retrieved December 28, 2002].

Brown, L., Sherbenou, R. J., & Dollar, S. J. (1982). *Test of nonverbal intelligence*. Austin, TX: Services for professional Educators.

Bruner, J. (1983). *In search of mind: Essays in autobiography*. New York: Harper & Row.

Bruner, J. S. (1960). *The process of education*. New York: Vintage Books.

Bruner, J. S. (1971). The process of education revisited. *Phi Delta Kappan*, 53.

Carroll, R. T. (2002, August 20, 2002). *Pseudoscience*, [Web site]. SkepDic.com. Available: http://skepdic.com/pseudosc.html [2003, February 16].

Cunningham, C. M. (1995). *The effect of teachers' sociological understanding of science on classroom practice and curriculum innovation.* Unpublished Dissertation, Cornell University, Cornell.

D'Aleo, M., & Edelglass, S. (1999). *Sensible physics teaching*. Chestnut Ridge: Parker Courtney Press.

Davidson, N. (1993). *Sky phenomena: A guide to naked-eye observation of the stars*. Hudson, NY: Lindisfarne Press.

Dewey, J. (1930). *Human nature and conduct*. New York: Modern Library.

Dewey, J. (1938). *Experience and education*. New York: Macmillan.

Dewey, J. (1938). *Logic: The theory of inquiry*. New York: Holt.

Dugan, D., & Daar, J. (1994). Are Rudolf Steiner's Waldorf schools 'non-sectarian'? *Free Inquiry, 14*(2).

Durkee, P. (1974). An analysis of the appropriateness and utilization of TOUS with special reference to high-ability students studying physics. *Science Education, 58*(3), 343-356.

Edelglass, S., Maier, G., Gebert, H., & Davy, J. (1997). *The marriage of sense & thought*. Hudson: Lindisfarne Books.

Elkind, D. (1981). *The hurried child: growing up too fast too soon*. Reading, Mass: Addison-Wesley.

Engel, B. S. (1995). *Where are the children? Spheres of power, authority and responsibility and the reform of elementary education.* Paper presented at the AERA, SF.

Ennis, R. H. (1985). Goals for a critical thinking curriculum. In A. Costa (Ed.), *Developing minds: A resource book for teaching thinking*. Alexandria, VA: Association for Supervision and Curriculum Development.

Fraser, B. (1978). Development of a test of science-related attitudes. *Science Education, 62*(4), 509-515.

Gardner, H. (1991). *The unschooled mind*. New York: Basic Books.

Gardner, H. (1993). *Multiple intelligences: The theory in practice*. New York: Basic Books.

Goodlad, J. I. (1984). *A place called school*. New York: McGraw-Hill.

Goodman, J. (1988). Constructing a practical philosophy of teaching: A study of preservice teachers' professional perspectives. *Teaching and Teacher Education, 4*, 121-137.

Grohmann, G. (1999). *The living world of the plants: A book for children and students of nature*. Fair Oaks: AWSNA.

Haladyna, T., Olsen, R., & Shaughnessy, J. (1982). Relationships of student, teacher, and learning environment variables to attitudes toward science. *Science Education, 66*(5), 671-687.

Harlen, W. (Ed.). (1985). *Primary science: Taking the plunge*. Oxford: Heinemann Educational.

Harmon, M., Smith, T., Martin, M., Kelly, D., Beaton, A., Mullis, I., Gonzelez, E., & Orpwood, G. (1997). *Performance Assessment in IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: TIMSS International Study Center. Boston College.

Harwood, A. C. (1958). *The recovery of man in childhood: A study in the educational work of Rudolf Steiner* (6th ed.). Spring Valley, NY: Anthroposophic Press.

Haukoos, G., & Penick, J. (1983). The influence of classroom climate on science process and content achievement of community college students. *Journal of Research in Science Teaching, 20*(7), 629-638.

Heiss, A. (1930). Zum problem der isolierenden abstraktion.,, 285-318.

Hemmendinger, I. (1953). Perceptual organization and development as reflected in the structure of Rorschach test responses. *Journal of Projective Technology*(17), 162-170.

Hofstein, A., Maoz, N., & Rishpon, M. (1990). Attitudes towards school science: a comparison of participants and nonparticipants in extracurricular science activities. *School Science and Mathematics, 90*(1), 13-22.

Hofstein, A., Scherz, Z., & Yager, R. E. (1986). What students say about science teaching, science teachers and science classes in Israel and the U.S. *Science Education, 70*(1), 21-30.

Hunt, E., Frost, N., & Lunnenborg, C. (1973). Individual differences in cognition. In G. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 7, pp. 87-121). San Diego: Academic Press.

Hutchins, E. (1966, 1984). *The curriculum of the first Waldorf School*. London: Rudolf Steiner Publishing Company.

Iris, M. A., Litowitz, B. E., & Evens, M. W. (Eds.). (1988). *The part-whole relation in the lexicon: An investigation of semantic primitives*. Cambridge: Cambridge University Press.

Julius, F. H. (2000). *Fundamentals for a phenomenological study of chemistry*. Fair Oaks, CA: AWSNA.

Kintsch, W. (1989). Learning from text. In L. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 25-46). Hillsdale, NJ: Lawrence Erlbaum Associates.

Kolisko, E. (1945,1978). *Geology*. Bournemouth, UK: Kolisko Archive Publications.

Kraft, R. J., & Kielsmeier, J. (Eds.). (1995). *Experiential learning in schools and higher education*. Dubuque, Iowa: Kendall/Hunt.

Kuhn, T. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.

Lederman, N., & Druger, M. (1985). Classroom factors related to changes in students' conceptions of the nature of science. *Journal of Research in Science Teaching, 22*(7), 649-662.

Lesser, G. S., Fifer, G., & Clark, D. H. (1965). Mental abilities of children from different social class and cultural groups. *Monograph of Society for Research in Child Development, 30*(4).

Lowe, R. C. (1973). A developmental study of part-whole relations in visual perception. *The Journal of Genetic Psychology*(123), 231-240.

Lyons, J. (1977). *Semantics*. Cambridge: Cambridge University Press.

Marzano, R., Brandt, R., Hughes, C., Jones, B., Presseisen, B., Rankin, S., & Suhor, C. (1988). *Dimensions of thinking: A framework for curriculum and instruction*. Alexandria, VA: The Association for Supervision and Curriculum Development.

Masters, B. (Ed.). (1992). *Waldorf curriculum studies: Science in education* (Vol. 1). Callington, UK: Lanthorn Press.

Mayer, R. (1991). *Thinking, problem solving, cognition* (2nd ed.). New York: W.H. Freeman.

Mayer, R. (1992). Deductive reasoning, *Thinking, problem solving, cognition* (pp. 114-164). New York: W.H. Freeman.

Munby, H. (1983). Thirty studies involving the "Scientific Attitude Inventory": What confidence can we have in this instrument? *Journal of Research in Science Teaching, 20*(2), 141-162.

National Research Council. (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Nelson, G. D. (2001). Choosing content that's worth knowing. *Educational Leadership*(October), 12-16.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19*, 317-328.

Newell, A., & Simon, H. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

Norman, G. R., & Schmidt, H. G. (1992). The psychological basis of problem-based learning: A review of the evidence. *Academic Medicine, 67*(9), 557-565.

Oliver, J. S., & Simpson, R. D. (1988). Influences of attitude toward science, achievement motivation, and science self concept on achievement in science: A longitudinal study. *Science Education, 72*(2), 143-155.

Otto, P. B. (1997). *An investigation of the conceptual knowledge of four physical science concepts of a sample of preservice and inservice elementary school teachers from the midwestern United States and Taipei, Taiwan.* Paper presented at the Third International Conference on Reform in Teacher Education, Taipei, Taiwan.

Petering, J., & Mitchell, D. (2000). *Waldorf Science Newsletter, 6*(12).

Peters, J., & Gega, P. (2002). *Science in elementary education* (9th ed.). Upper Saddle river, NJ: Pearson Education, Inc.

Piaget, J. (1931). Le developpement intellectuel chez jeunes enfants. *Mind, 40*, 137-160.

Piaget, J. (1969). *Judgment and reasoning in the child.* London: Routledge and Kegan Paul.

Piaget, J. (1973). *To understand is to invent: The future of education*. New York: Grossman Publishers.

PLANS. (2003)., [World Wide Web]. Available: http://www.waldorfcritics.org [2003, March 1, 2003].

Prawat, R. S. (1995). Misreading Dewey: Reform, projects, and the language game. *Educational Researcher, 24*(7), 13-22.

Private Universe Project. (1989). *A private universe*. Cambridge, MA: Harvard-Smithsonian Center for Astrophysics.

Querido, R. M. (1982). *Creativity in education: The Waldorf approach*. San Francisco: H.S. Dakin Company.

Roth, W.-M., & Roychoudhury, A. (1993). The development of science process skills in authentic contexts. *Journal of Research in Science Teaching, 30*(2), 127-152.

Shermer, M. (1997). *Why people believe weird things*. New York: W.H. Freeman ad Company.

Shrigley, R. L. (1990). Attitude and behavior are correlates. *Journal of Research in Science Teaching, 27*, 97-113.

Snelson, J. S. (1993). The ideological immune system. *Skeptic, 1*(4), 44-45.

Sparks, R., & McCallon, E. (1974). Microteaching: Its effect on student attitudes in an elementary science methods course. *Science Education, 58*(4), 483-488.

Steiner, R. (1922, 1972). *A modern art of education* (J. Darrell, Trans. 3rd ed.). London: Rudolf Steiner Press.

Steiner, R. (1966). *The study of man*. London: Rudolf Steiner Press.

Steiner, R. (1967). *Discussions with teachers*. London: Rudolf Steiner Press.

Steiner, R. (1919,1966). *The study of man*. London: Rudolf Steiner Press.

Steiner, R. (1919,1976). *Practical advice to teachers* (J. Collis, Trans. 2nd ed.). London: Rudolf Steiner Publishing Co.

Sternberg, R. J. (1997). *Successful intelligence: How practical and creative intelligence determine success in life*. New York: Penguin Putman.

Sternberg, R. J., & Spear-Swerling, L. (1996). *Teaching for thinking*. Washington, DC: American Psychological Association.

Stigler, J. W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom*. New York: Free Press.

Stockmeyer, E. A. K. (Ed.). (1965). *Rudolf Steiner's curriculum for Waldorf schools* (2nd ed.). E. Sussex, England: Steiner Schools Fellowship Publications.

Strauss, A. L. (1987). *Qualitative analysis for social scientists*. New York: Cambridge University Press.

The Cognition and Technology Group at Vanderbilt. (1990). Anchored instruction and its relationship to situated cognition. *Education Researcher, 19*(6), 2-10.

The National Academy of Sciences. (1997,2000). *Science for all children: A guide to improving elementary science education in your school district*. Washington, D.C.: The National Academy of Sciences.

Thomas, J. A., Pedersen, J. E., & Finson, K. (2000). *Validating the Draw-A-Science-Teacher-Test checklist (DASTT-C): From images to beliefs.* Paper presented at the Association for the Education of Teachers of Science, Akron.

Trostli, R. (1995a). *Physics is fun!*: Octavo Editions.

Trostli, R. (1995b). *Physics is fun: A sourcebook for teachers*. New York: Octavo Editions.

U.S. Department of Education. (2003). *National Assessment of Educational Progress (NAEP)*, [http://www.doe.k12.ga.us/sla/ret/naep.html] [Accessed 2003, January 2].

von Baravalle, H. (1991, 2000). *Astronomy: An introduction*. Fair Oaks, CA: Rudolf Steiner College Press.

von Mackensen, M. (1992). *A phenomena-based physics* (John Petering, Trans. Vol. 1,2 & 3). Kassel, West Germany: Union of German Waldorf Schools.

Vygotsky, L. S. (1978). *Mind in Society*. Cambridge, MA: Harvard University Press.

Werner, H. (1957). *Comparative psychology of mental development*. New York: International University Press.

Wiggins, G. (2001). *Relearning by Design Summer Academy*. Princeton, NJ: Understanding by Design.

Wiggins, G., & McTighe, J. (1998). *Understanding by design*. Baltimore: ASCD.

Wilkinson, R. (1975a). *The human being and the animal world*. Fair Oaks: Rudolf Steiner College Press.

Wilkinson, R. (1975b). *Plant study and geology*. Fair Oaks: Rudolf Steiner College Press.

Wilkinson, R. (1975c). *teaching practical activities*. Fair Oaks: Rudolf Steiner College Press.

Wilkinson, R. (1978a). *Nutrition-health-anthropology*. Fair Oaks: Rudolf Steiner College Press.

Wilkinson, R. (1978b). *Teaching physics and chemistry*. Fair Oaks: Rudolf Steiner College Press.

Wilkinson, R. (1982). *Commonsense schooling*. Sussex, England: Rudolf Steiner Press.

Winston, M., Chaffiiin, R., & Herrmann, D. (1987). A taxonomy of part-whole relations. *Cognitive Science*(11), 417-444.

Wynn, C. M., & Wiggins, A. W. (1997). *The five biggest ideas in science*. New York: John Wiley & Sons, Inc.

Yager, R. (1991). The constructivist learning model. *The Science Teacher, 58*(6), 52-57.

Yager, R., & Yager, S. (1985). Changes in perceptions of science for third, seventh, and eleventh grade students. *Journal of Research in Science Teaching, 22*(4), 347-358.

Yager, R. E. (1982). Information from students concerning school science: implications for instruction for the gifted. *Roeper Review, 4*(4), 9-10.

Yager, R. E., & Penick, J. E. (1986). Perceptions of four age groups toward science classes, teachers, and the value of science. *Science Education, 70*(4), 355-364.

APPENDIX

The Waldorf Science Curriculum

The curriculum outline on the following pages was gleaned from a variety of Waldorf literature sources and organized in bullet points under 5 categories:

1. **From *The Curriculum of the First Waldorf School* (Rudolf Steiner)**
2. **Overview**
3. **Objectives**
4. **Topics (Subjects)**
5. **Strategies**

Waldorf Science Curriculum Outline for Grade 1

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)

"Knowledge of one's native land: This subject should be given in such a way as to awaken the dreaming child gradually to a consciousness of his environment, so that he learns to connect himself more and more consciously with his surroundings. Whatever is brought home to his understanding or raised to his consciousness- for instance the well-known plants, animals, stones, mountains, rivers and fields-must be presented by the teacher in an imaginative-moral way fitting to the age of the child, and never in abstract descriptions. For instance, the grandeur, the reverence, the gentleness or wildness of sky, clouds, stars, flowers, animals or stones, must be expressed and stressed as in fairy stories by means of the animated conversations these beings hold one with another."

Overview:

- Encourages a loving appreciation for the workings of the natural world.
- Dedication to careful observation of natural phenomenon.
- Loving appreciation for nature and its manifestations
- Appreciation for inter-connectedness of all nature
- Holistic vs. reductionist scientific discipline.
- Phenomena of natural world and its various elements are first approached
- Components are the foundations of a later scientific curriculum
- Awe for the natural world
- Understanding factual information is secondary to developing these faculties of awe, respect and inquisitiveness, as well as developing the child's sensory abilities to observe.
- The science curriculum in grade One consists primarily of the life sciences to support the alive, animated view that a 6-7 year old has of the world

Objectives:

- Reverence and awe for the natural surroundings
- A feeling that nature is alive and not mechanistic
- Understanding and appreciation for seasonal changes and effects upon nature.
- Promotes the connection young children have with the natural world.
- Enhance a child's wonder, curiosity and enthusiasm for the world and provides opportunities for a child to feel s/he is part of a whole living cosmos.

Topics (subjects):

- Nature stories
- Life Sciences
- Earth Science
- Seasons

Strategies:

- Nature walks
- Seasonal nature stories
- Sensory observation
- Informal discussion
- Drama
- Music
- Art
- First-hand experience

Waldorf Science Curriculum Outline for Grade ______2____

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)
"Writing, Speaking, Reading: From drawing and painting the capital letters the child should be led over to smaller script writing. He should learn to read. He should write down what has been told to him, and later on, give in quite short descriptions what he has learned about plants and animals, meadows and woods. The telling and re-telling of fairy tales should gradually give place to fables and animal stories. The child at this age is still so much connected with his surroundings that he gains the best understanding of animals when they speak and act as human beings. This is the character of the fable. The giving of legends brings into harmony what the child has experienced of the animals through fables, with the picture of the human being in his striving towards completion as represented in the legends. Therefore legends are necessary as an addition to the fables and animal stories."

Overview:
- Encourages a loving appreciation for the workings of the natural world.
- Dedication to careful observation of natural phenomena.
- Loving appreciation for nature and its manifestations
- Appreciation for inter-connectedness of all nature
- Holistic vs. reductionist scientific discipline.
- Phenomena of natural world and its various elements are first approached
- Components are the foundations of a later scientific curriculum
- Awe for the natural world
- Understanding factual information is secondary to developing these faculties of awe, respect and inquisitiveness, as well as developing the child's sensory abilities to observe.
- The second grade science curriculum strengthens and adds to the ideas of the first grade

Objectives:
- Reverence and awe for the natural surroundings
- A feeling that nature is alive and not mechanistic
- Understanding and appreciation for seasonal changes and effects upon nature.
- Support for a child's sense that s/he is connected to the wholeness of a life-filled world
- To perceive sensorially and to be curious are still the primary objectives of the curriculum.

Topics (Subjects):
- Nature stories
- Fables, Native American stories and stories of people who have dedicated themselves to the preservation of nature
- Life and earth sciences

Strategies:
- Oral responses to stories
- Artistic responses to stories
- Nature walks
- Nature activities

Waldorf Science Curriculum Outline for Grade ______3____

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)

"Lessons in Practical Life: At this stage the children should learn to connect themselves consciously with their surroundings. For instance they should learn of the preparation of mortar, and of its use in building. They should learn about the tilling, the ploughing and the manuring of the fields, and how to distinguish the different kinds of corn. They should come to realize that the animal needs the plant to feed it, and the plant needs the animal to fertilize it and the mineral to nourish it and give it firm support. This subject should awaken in the children a feeling for the wonderful working together of all things that live in the world, and should cause thankfulness to grow within them towards that which is below Man. But the teachers should always seek to guide the children from the world of the moral feelings to the world of practical life. In this way children can be given the foundation for the writing of business letters and compositions in the later school classes. It is very important that the teacher should give a careful preparation in these early stages for all that will come in the syllabus later on."

Overview:

- Child has entered into the dynamics of the nine year change
- Separateness from natural surroundings is taking hold of child
- Study of home surroundings moves into practical realm of human activities
- Important to stress socially cooperative nature of human activities at this age
- The child is shown the natural world as a place in which the needs of human beings can be met
- More emphasis is placed on the physical and earth sciences
- Help the children gain confidence in growing food, making shelter and clothing. They should learn that the latter is possible and useful.
- Spend a week on a farm

Observations:

- Love and appreciation for natural world through observational skills
- Develop understanding of various socially cooperative activities
- Describe various types of shelters constructed around the world

Topics (subjects):

- Life Science
- Earth Science
- Native American stories
- Physical Science
- Farming
- Clothing
- Animal Husbandry- interdependence of humans and domesticated animals
- Plant cultivation
- Soil conservation
- House building

Strategies:

- Examine and observe changes in nature through seasons
- Listen to nature stories
- Participate in nature walks
- Farming
- House building
- Hands-on involvement
- Oral work
- Observation of written work
- Observation of artistic work

Waldorf Science Curriculum Outline for Grade ______4____

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)
"Study of Home Surroundings: The more imaginative study of the immediate world around the child is now led over the History and Geography of the neighborhood. The historical development of the familiar objects of the surroundings should be given. For instance the teacher should describe how orchards or farms come into being and how various industries have sprung up.

Nature Study: In the ninth year of the child's life the teachers should make a transition from the imaginative moral treatment of the Kingdoms of nature to one where the child stands opposite natural objects in a more objective and understanding way. Exact Nature Study begins when the child has achieved a greater objectivity in his own being. In an elementary study of man, the "human being" should be represented in an artistic and reverent way. After this the animal kingdom should be studied but always in its special relationship to man. The teachers should describe single animals and compare their organisms with that of man. Thus the children learn to perceive how the manifold forms of the animal world are unified with order and harmony in the human being."

Overview:
- Child feels separate from natural surroundings.
- Stronger self-consciousness in child
- More inward and independent soul-life
- Transition from imaginative treatment to the child standing opposite the natural world.
- Learn to perceive how the manifest animal forms are unified in the order and harmony of the human being.
- Grade children study animals- their morphology, adaptations, homes, and their relationships to plants and human beings

Objectives:
- To instill a deep feeling of awe, appreciation, and respect for the animal kingdom.
- To develop a picture of "threefold physiology" (Nerve-sense, metabolic limb, and rhythmic heart-lung)
- Develop understanding of animal traits and environments animals live in
- Develop picture of animal kingdom with every animal species specialization
- Develop through drawing, painting, modeling, a sense of animal characteristics
- Develop artistic, descriptive skills based on observations of animal life, domestic, local and zoological
- Present a holistic picture

Topics (subjects):

- Animal Studies
- Human and Animal
- Life science
- Earth science
- Geography

Strategies:

- Drawing
- Painting
- Modeling
- Observation
- Teacher's stories
- Poems
- Write report on an animal
- Use of maps
- Dramatic demonstrations

Waldorf Science Curriculum Outline for Grade ______5____

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)

"Natural History: Some of the less known animals should be described to the children. From the study of man and then of the animal world the teacher passes on to the plant realm. Botany should always be studied in connection with the life of the earth as a living organism. At this period the child's active healthy longing for causality is satisfied in the right way if he is shown how a certain plant, in a special place and in special climatic conditions, develops this or that form in its different parts."

Overview:

- Zoology with lesser known animals being described
- True sense for plants as offspring of living earth should be imparted to the children
- Show ecological and morphological unity of plant with its environment
- Plants observed and studied in natural environment
- Looking at the individual plant parts and their roles
- To bring forth relationships, comparisons and contrasts- and to bring the material in an artistic way so that the feeling life of a child will be touched.

Objectives:

- Develop understanding of plants as standing between earth and sky
- Develop understanding of whole plant as organism which can only be known over time
- Introduce/develop image of four-fold plant (root, stem, leaf, flower)
- Show relationship between plant and insect world
- Develop sense for flower's relation to warmth and light
- Develop image of tree's relation to earth
- Develop appreciation for ranking in plant kingdom- from the lower to higher plants
- Develop exact observational skills

Topics (Subjects):

- Life science
- Earth science
- Zoology
- Botany (Plant Kingdom)
- Geography

Strategies:

- Sketching
- Painting
- Modeling
- Descriptive writing

Waldorf Science Curriculum Outline for Grade ______6____

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)

"Natural History: The teacher should continue to describe the plants and should then pass on to the realm of the minerals. Minerals should be observed only in connection with geography, they should not be treated separately. Only, for instance, when the child has gained a lively picture of the granite mountain range in contrast to the limestone landscape, should the teacher put before him fragments of granite and limestone.

"Physics: In this school year the child is ripe for the first physics lesson. Here also the teacher should follow the natural healthy way for the growing child; that is, the way from the artistic to the intellectual. From music the child should be led to acoustics and then the larynx should be described. Color and painting with which the child has been familiar from the beginning of school-life should lead on to optics, and to the phenomena of color and light. The eye should not be discussed. The child is not yet ready to appreciate the application of physical law to the operation of sense organs in a living body. The teaching of Heat, Electricity and Magnetism can be introduced, starting from phenomena and developing the general laws from them."

Overview:

- Main focus is geology/mineralogy
- Introduce physics
- Move from whole to part
- Nature of imagination should be fully engaged and precede the material, informational experience of the subject
- 4-5 weeks for physics block
- True science based on mystery of discovery
- Students must come to experience and realize the path of knowledge is difficult and very different from the stores of information with which they are inundated
- Teacher's responsibility to instill in students a sense of appreciation and awe of phenomena
- Emphasis is on how the earth is changing constantly and what is causing this change.

Objectives:

- Develop understanding that the mineral kingdom is built upon laws of cause and effect
- Develop understanding of constituent mineral parts of rocks
- Extract geological studies form actual earth forms in which they are found
- Enable students to observe and appreciate difference between variety of crystals and gems, metals, geographic and geologic formations
- Develop understanding for what constitutes discipline of physics
- Discipline and train observational skills
- Appreciate the phenomena of sound, light, heat, and electricity and magnetism
- Learn to write and draw exact descriptions and representations from observation

Topics (subjects):

- Geology/mineralogy
- Astronomy
- Physics
- Zoology
- Botany
- Acoustics
- Optics
- Heat
- Electricity
- Magnetism

Strategies:

- Demonstrations
- Observation
- Writing
- Drawing

Waldorf Science Curriculum Outline for Grade ______7____

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)

"Nature Study: In the previous school years the pupil has passed from the study of the human being down to the animal kingdom, then to the plant world and to the earth and the single minerals. Observation of nature now should lead him back again to man. The teacher should describe nutrition and conditions of health. At this end of true childhood and at the beginning of puberty the growing boy or girl is at the stage when he can bring understanding and feeling to the subject of nutrition and health without falling into the egoism with which older people generally approach these questions.

"Physics: The pupil should learn more about acoustics, optics, heat, magnetism and electricity; also he should learn to know the fundamental laws of the cylinder, the screw, and so forth.

"Chemistry: Starting from the familiar process of combustion the children are made acquainted with the first elementary ideas of chemistry. With the concepts already gained in Physics, Chemistry, Geography and Nature Study a general presentation of industrial and economic life is given."

Overview:
- Moving from the mysterious to the mechanically lawful aspects of the physics discipline
- Observation of outer nature should lead back to study of human being
- Elementary ideas of chemistry and how it doesn't exist in isolation
- 1/3 of the year devoted to the science curriculum
- Physics requires 4 weeks
- Students are approached with the scientific, cultural, artistic and practical sides of chemistry and how it relates to industrial and economic life.

Objectives:
- Further develop understanding of basic physics, with emphasis on basic mechanics
- Develop understanding of basic human physiology
- Develop understanding of basic inorganic chemistry
- Answer: how has the phenomenon arisen and how does it work?

Topics (Subjects):
- Physics
- Astronomy
- Intro to Chemistry
- Biology
- Health
- Human physiology
- Inorganic chemistry
- Acoustics
- Optics
- Heat
- Electricity
- Magnetism
- Mechanics

Strategies:
- Observation
- Written descriptions
- Drawing
- Reports

Waldorf Science Curriculum Outline for Grade ______8___

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)
"Nature Study: When a pupil is sent forth into life he should take with him a picture of man as the completion of the kingdom of nature, in fact as a microcosm. The markedly contrasting functions of the different organic systems and their harmonious working together should be made clear to him. He has already learned to understand illness and health in connection with the physical body and the soul-spirit being of man. As the pupil becomes ripe in his own development, the teacher can show the mechanism of the bones and muscles and the inner structure of the eye, that is to say he shows all that can be understood about man by means of concepts drawn from the realm of mechanics and physics.

"Physics: The teacher should continue the work begun in the sixth Class and now show its practical application. He should lead on to the teaching of hydraulics, aeromechanics, climatology and meteorology.

"Chemistry: The importance of chemical process for industry is shown and the nature of the organic substances starch, sugar, protein and fat and their significance for human nutrition are studied."

Overview:

- Continued work with geology, physics, and chemistry
- 6-7 weeks needed for physics
- Whole block needed for chemistry and physiology
- Blocks take 1/3 of the year
- Capacity for logical thinking and independent judgment increases
- Student looking out into the world and the future
- Idealism and how knowledge and technology can serve humankind is very important
- Practical applications of physics
- Study of skeletal and muscular systems in physiology
- Also in physiology study of the nervous system, ear, and reproductive systems can be taught
- Wanting to do, to discover, to know and to find relevance in their studies by extrapolating from the classroom to the outside world
- Why, Where, and Who

Objectives:

- Further develop understanding of basic fields of physics
- Deepen understanding of basic human physiology
- Develop understanding of skeletal and muscular systems
- Develop understanding of basic organic chemistry and its practical applications

Topics (Subjects):

- Geology
- Physics
- Chemistry
- Physiology
- Anatomy
- Acoustics
- Optics
- Heat
- Electro-magnetism
- Hydraulics
- Hydrostatics
- Meteorology
- Aeromechanics
- Industrial/technological revolutions
- Skeletal/muscular systems
- Nervous system
- Ear
- Reproductive system
- Organic chemistry

Waldorf Science Curriculum Outline for Grade ______9_____

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)
"Nature of Man: The study of the nature of man should be continued.
Chemistry: The elements of organic chemistry should be taken.
Physics: The two most important means of communication, the locomotive and the telephone, are explained. Heat and mechanics are treated until the locomotive can be understood; electricity, magnetism and sound are taken in relation to the telephone. In addition, the motion of the stars in the direction of vision and the Doppler effect are discussed as far as the maturity of the pupils will allow. The necessary optics for this is also treated."

Overview:
- 10 days spent living on a farm and participating in farm activities
- Study structure of bones, joints, cartilage, muscles…
- Principles of sound and thermodynamics are investigated
- Demonstrations of simple substances into more complex substances

Objectives:
- Geological phenomena studied to create both a global and local view of geology

Topics (subjects):
- Organic Chemistry
- Physics
- Biology
- Geography
- Anatomy
- Farming
- Geology
- Sound, communication, Thermodynamics and Engines
- Health

Strategies:
- Experiment
- Discussion
- Hands-on farming
- Observation
- Demonstration

Waldorf Science Curriculum Outline for Grade ______10_____

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)
"Natural Science: In anthropology, the teacher should describe the organs and their functions in relationship with the life of soul and spirit. We should now proceed to ethnography, starting with a study of the human being as an individual. We should also take here mineralogy and crystallography, linking up these subjects with the Geography lessons in which we have described the earth structurally and physically as a whole. We should study the process of the forming of limestone, and its significance throughout the whole earth, as well as in the human and animal organism where it is found in the skull and bone formations. We can then contemplate how the human being has partly to overcome this natural hardening process in order not to become as hardened as the animals. We should also study the metals, giving an exact description of their appearance, their chemical reactions, and their geographical position including their effects on the human organism.
Chemistry: The teacher should describe acids, alkalis and salts, and with the help of these leading concepts the pupil should be introduced to the various chemical phenomena and should also discover how these processes are revealed in the living organism. "Acid" and "Alkali", for instance, remain dead concepts as long as the pupil does not realize that the polarity between them is active in a living way throughout nature, especially in the plant, the animals and in man. In this way we gradually rise from the mere study of the various acids and alkalis from the point of view of inorganic chemistry to an understanding of such contrasts occurring in the animal kingdom as for example between acid food juice and the alkaline blood fluid of the bee.
Physics: Mechanics should be taken up to simple machines and projectiles. The parabolic nature of the trajectory of projectiles is worked out."

Overview:
- Laws of force are studied
- Experiment-based development of acids/bases/ salts.
- Study of interaction of air, water, earth and the sun's heat on weather conditions
- Functions of endocrine system as well as sexual maturation

Objectives: See Part C.

Topics (Subjects):
- Chemistry
- Physics
- Biology
- Geography
- Physiology
- Meteorology
- Acids/bases/salts
- Climatology
- Inorganic chemistry I
- Health

Strategies:
- Experiments
- Discussion

Waldorf Science Curriculum Outline for Grade ______11_____

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)

“Nature Science: In this course should be taken structures of cells, and Botany as fat as the Monocotyledons. The teacher should characterize the cell so that the pupils are always aware of the great cosmic relationships which are mirrored even in the smallest substances; for instance when cells divide they repeat the primeval cosmic activities from which they have their being. In Botany it is important to describe the plant in connection with the soil in which it grows and with the influences of the whole universe.

Chemistry: An attempt should be made to give a survey of the whole field of chemistry by extending the concepts of acid, alkali and salt. Any separation between inorganic and organic chemistry should be avoided. The presentation should be based on the chemical processes rather than on the chemical elements and the study of the qualities of acid, alkaline, salt-like combustible should precede that of the individual substances. Sulfur for example could be described in such a way that it is primarily regarded as a sulfur process which can be characterized as a part of the volcanic processes of the earth, but also as the force, active in living protein, accelerating and invigorating metabolism in plant, animal and man. The teacher can characterize the substance sulfur as a part of the universal sulfur process in nature, which has come to a standstill as a frozen and hardened fragment. Each substance can be treated in this way. In this permeating all life processes of the earth as, say, sugar or other carbon compounds. Through this way of teaching that which has become rigid and hardened as “matter” can be brought back to life if it is shown how this “matter” turns into an all-embracing process in world and man.

Physics: The pupils should study the more modern developments in the realm of electricity, such as telegraphy wireless, x-rays, radioactivity, and so forth.

Technology: The teacher should describe water wheels, water turbines, and steam turbines, and make cardboard models. He should speak in great detail of paper factories, and excursions should be made over factories, for instance the pupils should visit a power plant.”

Overview:

- Characteristics of electric and magnetic fields are investigated and studied
- The periodic table is developed through experiments and history
- Characteristics of planets, stellar evolution, galaxies are studied.
- Study of morphology of algae though gymnosperms

Objectives: See Part C.

Topics (Subjects):

- Chemistry
- Inorganic chemistry II
- Physics
- Biology
- Biology Lab
- Electricity/ Magnetism and nuclear physics
- Periodic table
- Astronomy
- Botany
- Environmental science

Strategies:

- Experiment
- Observation
- Discussion

Waldorf Science Curriculum Outline for Grade ______12_____

From *The Curriculum of the First Waldorf School* (Rudolf Steiner)
"Natural Science: In Botany the phanerogams should be studies, and this should be followed by a summing up of the Zoology courses. The most important representatives of the animal world should be described and these should be understood as differentiations from the single organic system of the human being into the single organizations of the animal groups. Each animal appears as an elaborated organ or limb of the human being. The animal world is the human being separated off into parts. Thus at the end of his school life the pupil should grasp scientifically what he learnt as a child in his first school days in pictures, in fables and in the simplest lessons in zoology. At the same time all realms of nature should be seen together in a united whole, with the study of man as a central theme running through all the lessons.
Chemistry: This subject should also be brought to a conclusion. Through examples the pupils should be enabled to realize how the processes within man, for instance formation of pepsin, etc., are something totally different to those in outer nature.
Physics: Optics is taken: light as such, light and matter, photometry, mirrors, refraction and consequent distortion of images. Origin of color, polarization, double refraction
Technology: In the study of this subject the pupils should gain a knowledge of raw materials, their origin and their transformation; this should be given in connection with modern developments in economics and labor. Industrial districts should be visited."

Overview:

- Lawfulness of optics is determined through observation of optical phenomena
- 9 week elective course in mathematical physics for solving physics problems, which are mathematical in nature
- Experiment based organic chemistry – transforming substances into more complex organic molecules
- Previous learned material is applied to human biochemistry
- Study of life cycles and morphology of major animal phyla
- Study of human embryology; function of organ systems

Objectives: See Part C.

Topics (Subjects):

- Physics
- Biology
- Honors program and AP (Varies with school)
- Organic Chemistry
- Bio-chemistry
- Physiology
- Zoology

Strategies:

- Observation
- Experiments
- Models