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ABSTRACT

This paper is a review of the literature concerning the history and current state of blended science instruction. The goals of blended science instruction are to provide learners with a liberal science education and to develop scientifically literate citizens. The term "blended science instruction" refers to various means of reconnecting traditional instructional disciplines. This paper reviews the integrated, unified, and coordinated approaches to science instruction. It also addresses the philosophical, psychological, pedagogical, and pragmatic justifications for a blended science curriculum; student assessment within blended science instruction; and teachers' self-efficacy and resistance to change. The difficulty of replacing traditional departmentalized curricula is noted, and the benefit to students of making changes that will enhance their ability to understand is stressed. Contains 63 references. (DDR)

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by

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Introduction

Science education, like most academic disciplines, has gone through cycles of crisis and reform encouraging invention and rediscovery of both instructional plans and pedagogical perspectives. One plan gaining renewed prominence in science teaching is the scheme by which the discrete science disciplines are taught together in some reconnected fashion. Two of the major trends in secondary science curricula and instruction from 1960 to 1990 relate to blended schemes (Kelly, 1993). Throughout this paper, we will use the label 'blended science' not to invent new terminology, but to focus on the common strengths and weakness of plans that individually are called integrated, unified, and coordinated science instruction.

Showalter (1973a) discussed unified science metaphorically, where he said:

> Just as a prism breaks white light into a spectrum of separate colors in a process similar to the typical orientation of our present specialized science courses. When a second prism is oriented correctly, it can refract and reunite the individual spectral colors back into ordinary light. (p.7)

Blended science instruction is designed to act as the second prism by reuniting the separate science disciplines into a more meaningful whole to "enable the learner to see science as a single humanistic effort, to understand the full scope and limitations of science, to avoid repetitions of subject matter. . ." (Showalter, 1973b, p. 26).

Teaching science without the artificial boundaries of the traditional science disciplines may lead students to a more meaningful learning experience and to reach higher levels of scientific literacy. In the real world of science, the science disciplines are not isolated from each other or from other intellectual fields as they are in school. Such separation is an artifact of how science is studied not how science is done. A holistic view of the sciences provides a richer intellectual understanding than is typically provided in classroom that focus on the facts and concepts of a single discipline. Advocates of blended instructional plans see them as better ways of helping students utilize the science meanings in daily life by teaching science in a connected and context-rich fashion. Even interpreting news stories and other issues that affect every citizen's life require the kind of integrated approach that blended science can provide. What may be discovered when reviewing the history and literature of blended science curricula is fascinating and worthy of review particularly with the present renewed interest in coordinated, integrated, unified, and other blended instructional plans.

In that regard, there are two major tasks in this article. First we will provide an overview of the blended curriculum ideology and discuss the design of three major blended science instructional plans. In comparing and contrasting these projects, we will examine the strengths and weakness of such proposals as a group and examine their relevance for today's learners. As a second task we will study the historical development of blended science plans, and synthesize the strengths or promises from these three blended instructional plans through philosophical, psychological, pedagogical, and pragmatic lenses (Blum, 1973; Horton, 1981; Showalter, 1973c). In addition, the commonly encountered issues or problems related to the implementation of a blended science curriculum will be presented.

The Historical Development of Reconnecting Instructional Disciplines

From 1875 to 1883, the child-centered curriculum advocate Francis Parker, fought against what he called unnatural learning. Parker believed that knowledge as naturally encountered by children in daily life should be the basis of the school curriculum. In other words, the school curriculum should be developed around daily issues and as such will enhance the learners' intellectual ability. De Garmo (1895) asserted that schooling had two major tasks; one is to teach separate subjects to fulfill pupils' content knowledge need and another to provide and teach the connections between disciplines. Herbart (1895), also an advocate of a life-based curriculum, did not agree with the fragmentation of school curriculum or teaching subjects separately. He promoted the notion of the unity of knowledge and claimed that the curriculum fragmentation should be replaced by proper instructional strategies that teach integrative knowledge. These early efforts led educators to debate which curriculum approach was most appropriate, discrete subjects or integrated (Longstreet & Shane, 1993).

Eisner (1992) pointed out that as early as the 1920s curriculum integration through thematic instruction was widely advocated. Furthermore, during the late 1960s, the discipline-based approach to science instruction was criticized for dwelling too much on theory and ignoring the need for practical application (McNeil, 1985). As a result of recognizing the need for social relevancy, a new trend to humanize the science emerged; accordingly, various kinds of blended approaches to science instruction appeared. Adams (1971) reported that in 1969, there were thirty curriculum projects in the United States that could be identified as integrated. The blended science instructional plans primarily funded by National Science Foundation such as the theme-based Unified Science from Ohio State University. In the meantime, the American Association for the Advancement of Science initiated an inquiry- or process-based science program, Science-A Process Approach (Hall, 1978). In 1972, Lockard found sixty-five instructional projects of an integrative nature and just two years later, Lockard (1974) discovered that the total number of integrated projects had grown to one hundred and twenty-two. Those increasing number of projects designed to reconnect the science disciplines define a major curriculum trend. However, when the back to the basics movement began in the 1970s, the blended science curriculum movement slowed dramatically.

Kahl and Harms (1981) in Project Synthesis, a metaanalysis of pre-college science education studies and a assemblage of future research activities, predicted that themes of human adaptation to meet personal, social, and career needs of individuals should be and will be the major trend for science education. A call for reforms in science education was initiated by a landmark study by the United States Department of Education, A Nation at Risk (1983). In the report of indicators of the 'risk', the National Commission on Excellence in Education testified one of the indicator is that "there was a steady decline in science achievement scores of U.S. 17-year-olds as measured by national assessments of science in 1969, 1973, and 1977" (p.5). To follow up the report, one response from the NSF was to conduct a nation-wide study of science curriculum in the mid 1980s, which revealed a mismatch between the existing science curriculum and what ninety percent of the students want and need. As a result, the NSF reinitiated the need for a coherent and meaningful curriculum, thus, blended reconnecting science disciplines was recalled toward themes to meet personal, social and career needs of individuals. By the late 1980s, ideas of reconnecting the science subjects started to reappear in influential documents such as the California Science Framework, which includes the goal that "In order for science to be a philosophical discipline and not merely a collection of facts, there must be a thematic connection and integration" (California Department of Education, 1990, p. 2). In 1989 another strategy to reunite the sciences, Scope, Sequence, and Coordination (SS&C) was initiated by the National Science Teachers Association (Aldridge, 1989). Lately, aspects of blended science are also recognized as directly aligned with philosophies in current national science education standard documents, such as Benchmarks for Science Literacy (AAAS, 1993), and the National Science Education Standards (NRC, 1996).

Blended Science: Integrated, Unified, and Coordinated

Educational reform is occasionally marked by the introduction of new labels for changes in existing strategies. Such is the case with the various attempts to blend science instruction called integrated, unified, and coordinated science. For instance, although unified science was actively promoted in the late 1960's and early 1970's, the term hardly appears in recent reports with its place taken by the term integrated science. Yet, in the 1990 UNESCO conference report on New trends in integrated science teaching, one still can see the interplay between the vocabularies of "integrated" and "unified". Today, the term integrated science has become the commonly-applied name for any science instruction which involves meaningful connections across separate subjects. Although in their purist forms distinctions can be made between the various ways to blend the sciences.

In the following section, the major plans for blending science instruction, integrated, unified, and coordinated, will be examined as initially proposed. A review of the science education literature reveals that most blended science instructional programs have evolved by changing their initial ideologies. Blurred definitions and vague concepts can be one of the factors that dooms a promising innovation, and in order to have in-depth understanding in how a blended science curriculum can play a role in schools, it is necessary to have a clear picture of *what* approach will be suitable to the unique needs of a school and *how* to adopt it (Yager & Lutz, 1994).

Integrated Science

Showalter (1996) describes integrated science in the 1960s contained elements of science and one or more other 'realms' of knowing as described by Phenix (1964) in his influential book Realms of meaning. Thus, an integrated science unit might contain science and history or science and literature. In addition to subject integration, Hurd (1991) states that an integrated science curriculum must reflect modern content focusing on higher-order thinking, learning-to-learn skills, and the application of science to human affairs.

Today, most integrated science programs involve plans in which two or more previously-separate school subjects are taught together in some connected fashion (Drake, 1993; Fogarty, 1991; Yager & Lutz, 1994). Such blending is typically at the discipline or theme level. Discipline-oriented integration is the initial form of integrated science, which focuses on the teaching of separate subjects with connections. Most frequently recognized approaches were identified as interdisciplinary approach and multidisciplinary approach (Drake, 1993). The interdisciplinary approach may involve several teachers from different disciplines teaching a class called Science 1. Each subject is presented when the concept required specific elaboration. Multidisciplinary approach is conducted by several teachers plan curriculum together with consensus of what will be focused and targeted in that semester. Teachers still teach in their own field in separate classroom but connecting to each other's subject-field. This approach reflects the earlier ideas of De Garmo's.

Theme-oriented integration does not emphasize the discrete subjects (Hurd, 1973), but instead is either content-, process-, or problem-directed. A content-directed thematic approach uses key concepts, principles, and generalizations of science as the center of instruction. Knowledge from separate sciences is taught to elaborate the content. For instance, a big idea such as "change," will be the theme for a study unit and any concepts related to this theme from each subject will be studied in depth. The process-directed thematic approach adopts Dewey's (1900) strategy for "Learning by doing". In such a plan, students might work on a project in a local scientific laboratory to learn science. The problem-directed thematic approach adopts the idea of child-centered curriculum proponents such as Parker. In the problem-based plan, an issue or problem that surrounds an individual will be identified, such as the problem of the mice's population. What factors affect the increase or decrease of the population will be extracted from each discipline and studied intensively. With the assistance of teachers, students will be led to the information necessary to try and solve the problem. It is the real-life-related issues of this approach that provide the link to help the connections of knowledge. In the following, a chart of proposals for making connections in integrated science curricula is presented.

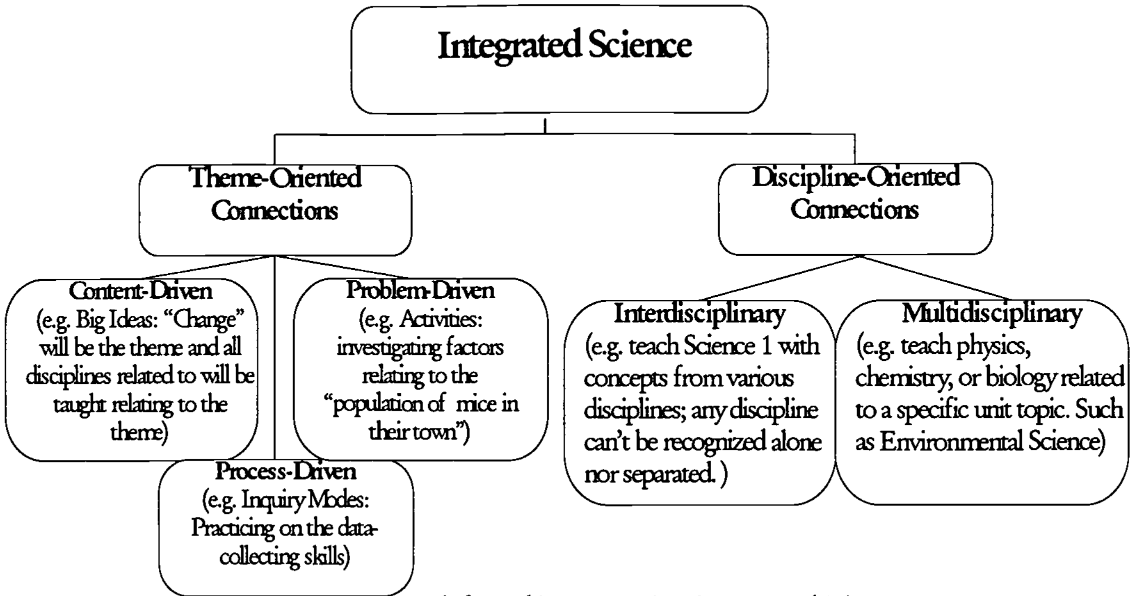

Figure 1: Proposals for Making Connections in Integrated Science

Unified Science

Unified science is typically thematic in its orientation, blending several science subjects and at least one of the social studies. Showalter (1996) explains their initial ideas for the term of unified "because that was what Einstein and others had used to label their efforts to come up with one theory to explain everything because everything had underlying similarities that were more important than the distinctions among the individual lines of thought." In the initial plan, a unified science program was defined "operationally as an approach to developing instruction in which each UNIT of study contained elements of two or more of the traditionally separate sciences." In addition, in terms of a unified philosophy based on Philip Phenix ideas expressed in REALMS OF MEANING: six ways of knowing (realms of meaning) were identified based on "the nature of the knowledge generated" and "the processes by which new knowledge is generated." Science thus includes the usual "hard" science disciplines as well as the behavioral and social sciences.

The Federation for Unified Science Education (FUSE) was founded at the Ohio State University in 1966 as a professional association of science teachers allied to provide mutual support for the development of unified science units. FUSE stressed that a general education in science for all young people should be the goal in grades K-14. In 1972, the Center for Unified Science Education (CUSE) was established to help local schools implement unified science curricula by conducting workshops and producing publications of instructional resources and services (CUSE, 1972; Thomson, 1975). However, the rise of the back to basics movement during the mid-1970s eliminated the funds for the development of furthered integrated schemes (Case, 1988).

Showalter, one of the first proponents of unified science, stated that certain characteristics of science permeate all the science subjects, chemistry, biology, physics, and other sciences (Showalter, 1973b). Such characteristics include questioning attitudes, the processes of collecting and interpreting data , and the concept of system. These are aspects of science that every student must learn in addition to the existing scientific facts. Showalter (1973a) considers concepts (energy, change, equilibrium), processes (classifying, interpreting data, identifying variables), natural phenomena (rivers, crowds), and problems (community energy supply, air pollution) as useful curriculum organizers. These four organizers can form the basis for the orientation of the curriculum with instruction developed to surround that theme. These four unifying themes, in Showalter's view, also reflect the basic philosophy of a unified science approach with science as a unity. Herbart's (1895) idea of achieving a unity of knowledge was well applied in unified science.

Today, it is difficult to distinguish unified science curricula from integrated science curricula. In fact, as stated previously, unified science is hardly mentioned in current science education literature. However, what distinguishes the unified science from integrated science is its sole focus on the unity of knowledge implemented by a thematic approach, whereas, integrated science is generally believed to encompass both theme-oriented and discipline-oriented strategies. In addition, in the initial plan of integrated and unified science, integrated science refers to science integrating with other realms of knowing, whereas, unified science considered "aspects of social science as legitimate components" (Showalter, 1996).

Coordinated Science

Coordinated science curricula is a form of discipline-oriented integration reflecting De Garmo's early ideas about teaching the separate science subjects by providing connections. Aldridge (1989) described the Scope, Sequence, and Coordination (SS&C) project as a response to the situation in which students typically meet with separate teachers in separate classrooms at separate times within a framework providing the scope or visions of learning objectives for each grade level in a sequential and coordinated fashion. Each teacher instructs on the basis of those predetermined scopes. Moreover, two or more teachers work and plan together to reinforce and cross-link topics and objectives of their individual specialties. Topics of instruction (which can be concepts, principles, laws, and theories) in each science discipline is treated in a 'spiral approach' fashion; that is, the topic is revisited every year but the level of abstraction is increased at higher grade levels (Aldridge, 1992). In practice, a student may be enrolled in biology, chemistry, and physics each year to study a particular concept at different intellectual levels. The traditional 'layer cake' format of specialized science teaching with one science each year is cut through with links joining the courses together with the key topic revisited.

Although SS&C has created renewed interest in blended science instructional plans, the idea for coordination is not new. In 1973, Showalter, Cox, and Holobinko defined a coordinated science program as a curriculum structure in which a science course is planned and taught in parallel with other science or non-science courses. Today, those schools that have adopted the SS&C orientation do so in various forms. Some plans are not applying the discipline-oriented approach in terms of teaching separate subjects. Instead, these schools applied a thematic approach which extends beyond the initial SS&C format. This choice is not dichotomous (Black, 1986), either theme-oriented or discipline-oriented, but the purpose of this curricula review only serves to depict rationale of instructional approaches behind various format. The choice of orientation should depend on the goals for instruction.

The Promise of Blended Science Instructions

We recognize that each of the strategies discussed makes unique contributions to science instruction but, as a group, integrated, unified, and coordinated science organizational plans can be recommended from a number of shared perspectives. These areas of strength include rationales from philosophical, psychological, pedagogical, and pragmatic domains.

Philosophical Justifications for a Blended Science Curriculum

The primary philosophical justification for blended science teaching is that nature itself does not make the kinds of discipline-based distinctions we frequently do when designing science instruction. This point was made well by Adams (1971) who said:

> Nature does not categorize her phenomena as she presents them to us from moment to moment, day to day, year in and year out. These phenomena which occur continuously are a part of a large mosaic of interrelated events. . . (pp. 495-496)

If we accept the idea that there is unity in nature, then it is logical to recommend that science should be taught in a blended fashion. Slesnick and Showalter (1961) and Rutherford and Gardner (1969) suggested that in order to understand nature holistically, people must study nature within the context of its interrelationships. What we learn from nature should be learned as a whole not as unrelated pieces of information typically provided in the study of specialized or fragmented subjects. Current science instructional orientations must shift away from an emphasis on science as a body of knowledge toward an emphasis of learning experiences which include both the products and processes of science. What goal will be emphasized in a blended science approach is the nature of science itself which fostering an application in students of the elements common throughout the sciences.

Hodson (1988) further pointed out that there should be a place in the curriculum for interdisciplinary studies in which important, controversial, and interesting topics are viewed from the standpoints of scientists, historians, economists, and any experts in specialized fields. Blending science instruction with other disciplines can show the human dimension of the discipline. Scientific research is a humanistic activity, not an activity belonging to a select few (AAAS, 1989, 1992; NRC, 1996).

Psychological Justifications for a Blended Science Curriculum

Teaching science in a blended fashion is recommended from a psychological perspective. This recommendation stems from the realization that students have difficulties in making connections between discrete pieces of knowledge. In traditional classrooms, students typically learn subjects separately and struggle to make connections themselves (Hall, 1978; Hurd, 1991; 1973; Taylor, 1973; Yager & Lutz, 1994). Cognitive psychologist Jean Piaget (1964) stressed that pupils' cognitive abilities develop in stages and that child's thinking processes gradually shift from concrete to abstract intellectual functioning. Since a child's developmental stage sets certain limits on learning, when a child has not shifted to a higher intellectual functioning level, she or he may not be able to understand how to incorporate learned concepts with information presented in subsequent classes.

Gagne (1965) and Thorndike (1913) suggested that only limited transfer of concepts, principals, and strategies occur from one learning situation to another. In traditional classrooms, students are expected to make their own connections behind the information learned in one class and material from different courses. Blended science schemes provide the most meaningful learning experiences because concrete linkages between science will be encouraged by the design of the course rather than hoping that such links will be found by the students.

Moreover, unlike discrete science instruction presenting the concepts as a fixed body of facts, principles, and definitions, courses in which the science disciplines are united propose that learning should be meaningful to learners in order to be able to construct knowledge meaningful to themselves. This aligns with constructivism, which believes that learning is an interpretive process, new information is processed only within the spectrum of an individual's prior knowledge or experiences (von Glaserfeld, 1987). Science concepts are always criticized too distinct from real life. Reconnecting science disciplines around the issues meaningful to learners will be a better approach for not only learning but also knowledge construction.

In addition, motivation is another important psychological issue. If information gained in science classroom is not related to phenomena or incidences, one actually experiences in real life, it is likely that students will have low interest in science. From a blended sciences approach, meaningful science instruction related to individual learner helps students to cultivate positive scientific attitudes; attitudes to science learning not only as a study of important scientific concepts but also as a study of critical views and reasoning ability information of daily life, and as a study of enabling one to observe and to think scientifically about natural world.

Pedagogical Justifications for a Blended Science Curriculum

Teachers represent the single most important element in the development of effective interdisciplinary science programs (Worthington, 1972; Drake, 1993). Blended science plans can enhance teaching by promoting collegiality among educators, as required when teachers are asked to teach in practice beyond their training, or in theme beyond their experiences. Blended instruction requires team work, interaction, and communication if the boundaries between subjects are to dissolve as subjects are presented in a meaningful and connected fashion. While there may be some reluctance and frustration among teachers who are making the transition to blended science, many will find such opportunities exciting, interesting, and a source of renewal.

Since blended science has among its goals both synthesis and conceptual understanding on the part of students, such classrooms must change from being teacher-centered to student-centered. The role of the teacher will become a facilitator of learning not an imparter of fixed scientific facts. This may be a challenge for many educators but at the same time may represent an opportunity for professional growth.

Pragmatic Justifications for a Blended Science Curriculum

One of the most important aspects of blended science curricula is how the outcomes of such plans compare with traditional schemes. In addition to being exposed to relevant science information, it is reasonable to ask if children who emerge from blended science courses are more livelier, more motivated, or more interested in scientific aspects of the world around them. Such attributes were found to be associated with students participating in unified science classrooms (Richardson & Showalter, 1967). Students in unified science programs had more interest in science, more understanding of science and its applications to social experiences, and were more scientifically-literate. In addition, unified science programs were found as effective as traditional classes in preparing students for college science (Showalter, 1968). Recently, Eggebrecht, Dagenais, Dosch, Merczak, Park, Styer, and Workman (1996) report that students in a second year integrated science program have better conceptual and skill outcomes than students in a traditional disciplinary sequence, with more student engagement. Prescott, Rinard, Cockerill, and Baker (1996) found that by presenting real-world applications before abstract scientific concepts, within an integrated curriculum, students were helped to make sense of science while encouraging their interest in the processes of science. Lopez (1996) found that blended science schemes expose students to the nature of science in a more complete way when compared with students in traditional discipline-distinct science classroom. Downing (1996) studied over 4000 matched-pair of traditional biology students and SS&C students with respect to their biology content achievement. Even the biology content achievement shows no significant difference, yet he found the statistically significance in students electing further science courses and are more likely to become college science majors. All these findings point out that even though not all blended science experiences are created equally, the results of such programs should encourage the use of blended science instructions in the future.

Any move away from traditional instructional plans shall be made advisedly and only when present schemes are not effective or when new strategies offer significant promise. With the release of the new National Assessment of Educational Programs results (Jones, Mullis, Raizen, Weiss, & Weston, 1993), we know that our past practice has not been effective. Science achievement has remained relatively low and unchanged for decades. On the other hand, we have evidence that blended science instructional proposals can be recommended from the philosophical, psychological, pedagogical, and pragmatic perspectives.

The Perils of Blended Science Instruction

Although, there are strong reasons to recommend the use of a blended science instructional scheme, but there are some important obstacles to recognize and overcome before this approach can be realized. It is reasonable to assume that some blended science schemes demand more support than others, but the general obstacles identified and strategies suggested in the following sections pertain to most varieties of the interdisciplinary experiences.

Assessment of Student Learning within a Blended Science Curriculum

Blended science instruction has always been accompanied by questions of what and how to assess. Drake's (1993) experiences when working with teams of teachers indicate that the problem of assessment is always serious at the beginning stage. Parents, teachers, and school administrators want to make sure that students in blended science classes can compete successfully with their peers in traditional settings. In traditional science instructional plan, an ending or summative assessment approach is applied to indicate what students learned. Whereas, blended science curriculum encompasses 'what students learned' and 'how students learned', the beginning, middle or formative, and ending or summative assessment is considered. Current research regarding assessment issues, including authentic assessment and performance-based assessment, are actively applied in assessing students' achievement from blended science learning. Yet, problems associated with these alternative assessment strategies (Alternative assessment and technology, 1992) are inevitable associated with blended curricula.

Teacher's Self-Efficacy and Blended Science Instruction

A major obstacle to the development of a blended mode of science instruction relates to issues of teacher preparation and self-efficacy. Self-efficacy refers to one's belief in his or her own capability to execute a given task (Bandura, 1977). Teachers are not only concerned about their ability to apply a new instructional mode different from their usual practice, but are also concerned about a proposal quite distinct from their own professional training. Most secondary teachers were educated with reference to a particular science, and elementary teachers usually lack sufficient training in any science area. Therefore, it is reasonable that most teachers will feel uncomfortable when they are asked to teach classes beyond their preparation. Moreover, low self-efficacy, lack of beliefs in their own abilities of teaching blended science, might lead teachers to low motivation or less effective in implementing the curriculum. Since teachers' self-efficacy is closely associated with students' learning (Ashton & Webb, 1986; Gibson & Dembo, 1984; Woolfolk & Hoy, 1990), it is vital that teachers maintain their enthusiasm for teaching during a period when they may lack confidence in themselves.

To resolve these issues, teachers should be involved in both the decision to integrate and in the design of a blended curriculum. Given the varieties of available plans, it is likely that some may be less threatening to teachers than others. This should be considered by these helping to encourage a shift away from traditional instruction. When teachers have a sense of control of their own teaching and have more confidence in their teaching ability, they will be more motivated to adopt the innovation.

Goar and Worthington (1972) suggested several strategies for helping teachers acquire the knowledge they may feel they lack. One of the ideas is that teachers from individual science disciplines work together as a team to assure that the main science ideas are enriched with depth. Cooperative or team teaching can help address the problem of depth and lack of security in teaching outside one's area of expertise. Another strategy is for the administration to provide support for teachers' efforts to gain the background knowledge they may lack and develop the program they themselves will be asked to teach. In fact, some educators may enjoy the challenge of broadening their content background and see this as an opportunity for renewal and professional growth. It is vital, however, that schools provide the time and finance the support necessary to all teachers to make this change (Drake, 1993). Moreover, encouraging teachers to read the literature related to the rationales for blended science should help them increase their support for commitment to the plan. In addition, increased discussion among teachers about their concerns and possible solutions is crucial if educators are to embrace rather than sabotage this innovation.

Teachers' Resistance to Change

Resistance to educational reforms is a typical reaction among teachers. In preparing to face teachers' resistance to a new plan, consideration of the change process is crucial (Hall & Hord, 1987). Individuals normally resist reforms generated or advocated by outside authorities. It is likely that teachers will see any innovation, not as an improvement, but as another chore. Researchers investing the change process suggest that teachers should be given opportunities to see the plan already in action in other school settings. When teachers see the results, they may start to be aware of and pay attention to the new program. Drake (1993) found that an effective way to start is to introduce integrated concepts into regular instruction units.

Shared visions are also important to facilitate change process (Hall & Hord, 1987). Teachers need to feel autonomous and empowered. By 'planning backward', teachers work with the educational community to set the intended outcomes from their students and put those standards as their directions of teaching. These intended teaching objectives are products of their engagement and correspond with their personal beliefs. And when there are reform projects at hand that correspond with their teaching goals, it increases the possibility of teachers accepting the change. Eggebrecht et al. (1996) suggest that all stakeholders should be involved in the reform. Communication among teachers, staff members, students, and the community on generating standards will provide the shared visions for the successful implementation of a blended curriculum.

Another concern is that scholars, such as Petr (1982), Hirsch (1987), and Bloom (1987), opposes the idea of interdisciplinary education by questioning the lack of depth. These reflections are interesting when compared with the findings from the recent Third International Mathematics and Science Study (TIMSS, 1996). Current science curriculum is mainly dominated by separate science teaching, a traditional teaching by the 'encyclopedia' textbooks, and become a curriculum of "a mile breadth but an inch depth". Whereas, blended science instruction, in general, emphasizes in-depth understanding over breadth, challenging a specific topic with in depth conceptualization but not some physics here and a little bit chemistry or biology there. Reconnecting various disciplines provides concrete links and anticipates learners to gain the ability to solve problems rather than take multiple choice tests, to be creative instead of conformitive to uni-standard answer, and to appreciate the processes of nature world instead of reciting scientific facts.

Conclusion

In summary, taking away the boundaries between the science disciplines will better prepare future citizens to face the changing world. However, replacing the traditional departmentalized curricula will not be easy. Although there are different plans for blended science instruction, all such strategies serve the goal of providing all learners a liberal science education with the goal of developing literate citizens. What we have learned from this review of the literature is that blending the sciences to form a new instructional direction is difficult. Yet, such difficulty must be tempered by what will best serve students in their quest for science literacy.

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