A STUDY OF INTERNATIONAL BACCALAUREATE SCIENCE TEACHERS' CHOICES IN CURRICULUM AND INSTRUCTION

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By

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

A STUDY OF INTERNATIONAL BACCALAUREATE
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CURRICULUM AND INSTRUCTION

presented by Lanett S. Jauss,

a candidate for the degree of
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ABSTRACT

This study was designed to investigate the choices International Baccalaureate (IB) science teachers make in curriculum and instruction. Data was gathered via a survey completed by IB science teachers who had attended either an April, 2007 workshop in Reston, Virginia or a January, 2008 IB roundtable discussion in Kansas City, Missouri. Surveys solicited the different choices IB science teachers make for options, Internal Assessment (IA) activities, Theory of Knowledge (TOK) emphasis, and demographics. Teachers' reasons for their option choices were also analyzed. Statistical analysis was performed using SPSS descriptive statistics, Pearson's product-moment correlations, and linear regression. It was found that IB science teachers' most frequent reasons for their option choices were related to ease, interest, background, and available resources. IB science teachers used a variety of IA activities, with hands-on activities and worksheets being most frequent. IB science teachers did not emphasize inquiry, although they did include some aspects of it among their choices. IB science teachers preferred to use activities they design or those designed by other teachers. Years of teaching experience, both total and IB, were correlated to the level of use of some TOK tenets.

CHAPTER I

INTRODUCTION

Increased rigor in curriculum is a continuous focus among researchers, educators, parents, politicians, and the public. Literacy in educational areas such as reading, mathematics, and science is constantly being examined. High stakes testing has become a reality, even though there are disagreements about its validity or what the assessments are actually measuring. Congressional legislation such as the No Child Left Behind (NCLB) Act have focused on the standards and accountability in the educational community, with schools in a constant race to meet the standards and achieve "adequate yearly progress" (NCLB, 2002).

There is also a drive to reach more diverse students in a multicultural push to educate all students at a high level. A recent report by the National Center for Education Statistics noted that there had been a "213 percent jump over the nine years of the study in the number of Hispanic students taking college-level Advanced Placement (AP) classes and a 177 percent increase over the same period for African-American students" (Viadero, 2007, p. 1), while the decrease in the number of students receiving a three or better on the examination was only six percent. A score of three on an AP examination is considered by most colleges to be the level students must achieve in order to receive college credit. The increase in the number of minority students who completed the AP examination, without a major drop in scores, was viewed as encouraging. This supports the drive for increased rigor for students.

In this age of high stakes testing and concern for increased rigor, literacy, and the positive social and intellectual development of our students there is one curricular program that has gained increased recognition as fulfilling many of the aspects deemed essential for a quality program. This program is the International Baccalaureate (IB) program. The mission statement of IB states:

> The International Baccalaureate aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect.
> To this end the organization works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment.
> These programmes encourage students across the world to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right. (International Baccalaureate, 2005-2007, Mission, p. 1)

This mission statement addresses concerns for rigor, for acquiring knowledge and inquiry skills, and for developing strong social development.

Description of the IB Program

The IB program consists of the following six subject areas: Group 1 (language), Group 2 (second language), Group 3 (individuals and societies), Group 4 (experimental sciences), Group 5 (mathematics and computer science), and Group 6 (the arts). Of these six subject areas, students are required to study three subjects at high level representing at least 240 hours of instruction and three subjects at standard level which represents 150 hours of instruction.

The core for these six subjects requires all students to complete three components. These include: an extended essay about a research topic of their choice; a theory of knowledge (TOK) class; and a creativity, action, and service (CAS) component where students volunteer in various programs and community activities. The extended essay requires the students to write a 4,000-word essay about a topic of personal interest. In the TOK class, students are encouraged to explore “the nature of knowledge across disciplines and other cultural perspectives” (International Baccalaureate, 2005-2007, Diploma p. 1). Along with the separate TOK class, there are TOK objectives included in each of the six subject areas. IB teachers are encouraged to teach some of the objectives while others are a required part of the tested curriculum. Participation in the CAS component promotes student involvement in the arts, sports, and community service so that they have an “awareness and appreciation of life outside the academic arena” (International Baccalaureate, 2005-2007, Diploma p. 1).

There are two levels of coursework for each curricular area in the IB program, standard and high level. Standard level includes 110 teaching hours with 80 of those hours designated for core topics and 30 of those hours for option choices. In addition 40 hours of practical work are required for a total of 150 hours of instruction. High level includes 180 teaching hours. Eighty of these hours are the same core topics as for standard level. An additional 55 hours are required for higher level material and 45 hours are required for options. Practical work for high level requires 60 teaching hours for a total of 240 teaching hours at high level.

Group 4 levels, both high and standard, include various science curricular components of topics, options, and internal assessment or practical work. The topics component is driven by objectives or IB assessment statements. These assessment statements are the knowledge and skills components which students are expected to learn. They are described in the curriculum guides for each subject and provide the knowledge base of the IB program.

The options component of the IB curriculum is a series of objectives which focus upon greater detail about topics of interest to a particular science content area. At each level teachers must choose two options to complete the requirements of IB. Examples of options include human nutrition and health (biology), medicine and drugs (chemistry), and quantum physics and nuclear physics (physics).

Assessment in the IB program is composed of two parts: the internal assessment (IA) and the external assessment. In the IA, teachers at the local school evaluate individual students’ work as a part of the subject’s course of study. The external assessment components are overseen by teachers at the local level, but are scored externally by IB trained examiners. These externally marked components form the greatest share of the assessment “because of the greater degree of objectivity and reliability provided by the standard examination environment” (International

Baccalaureate, 2005-2007, Diploma p. 1). These IB examinations are "light on multiple-choice questions and heavy on written essays" (Dwyer, 2006, p. B17).

The IA (practical work) portion of the IB curriculum includes 30-50 hours for investigations and a Group 4 project where all students are required to participate in an interdisciplinary science project emphasizing the processes involved in scientific investigations for up to ten hours. IA results are documented on a form called the Practical Scheme of Work (PSOW) form. The teacher records each student's experiences on laboratory investigations. These investigations, accepted by IB, may include laboratory practicals or projects which may be short or extend over a longer period, computer simulations, data-gathering exercises, data-processing exercises, and fieldwork. Teachers must document that they have included investigations over the entire syllabi with at least one investigation for each topic and option. Teachers then record the number of hours devoted to each activity. Finally, the teachers include their evaluations for the different IA categories. The evaluation scheme is outlined in the IB curriculum guide (International Baccalaureate Organization, 2007).

Teachers are encouraged to incorporate TOK components into their curriculum. Group 4 is "driven by emotion, using sense perception, enhanced by technology and combined with reason, it communicates through language, principally the universal language of mathematics" (International Baccalaureate Organization, 2007, p. 4). Tenets for Group 4 TOK are described in each subject's curriculum guide and included within several of the IB assessment statements.

Need for the Study

Numerous studies have been conducted which examined teachers' choices and the factors affecting those choices, both generally and specifically in science education (Aikenhead, 1984; Burris, Welner, Wiley, & Murphy, 2007; Deemer, 2004; Doyle & Ponder, 1977-78; Henry, 1994; Ingram, Louis, & Schroeder, 2004; Jones & Carter, 2007 Putnam, 1984; Schmidt, Porter, Floden, Freeman, & Schwille, 1987; Westerman, 1991; Yinger, 1979). These factors included practicality (Doyle & Ponder, 1977-78) and routine (Yinger, 1979) among elementary teachers. Schmidt et al. (1987) listed several factors affecting teacher choice, including teachers' beliefs, educational experience, district objectives and assessments, and the characteristics of students.

Westerman (1991) studied how factors influence expert and novice teachers differently. Henry (1994) reported informal student outcomes and teacher enjoyment as major factors affecting teachers' decisions, while Deemer (2004) focused upon school culture. Ingram et al. (2004) examined how the decisions teachers make are data driven where teachers look at the results on standardized assessments to make some of their decisions.

Aikenhead (1984), Jones and Carter (2007), and Pajares (1992) examined factors affecting science teachers' decisions. Aikenhead (1984) reported that science teachers integrate science content with practical classroom knowledge. Jones and Carter and Pajares discussed beliefs as having a great influence on a teachers' decisions. Burris et al. (2007) commented that IB teachers are affected by making sure there is depth rather than breadth in their curriculum.

All IB science classes have core curriculum, including objectives which are important to students' education. There are areas of choice called options. These options allow students to study in depth in areas like evolution, environmental chemistry, or mechanics.

Another area where teacher choices are made is in IB – IA. Practical experiences are considered important and certain guidelines for choices in this area has been discussed. In a recent report by the National Research Council (NRC), *America's Lab Report*, one of the conclusions drawn was

> Four principles of instructional design can help laboratory experiences achieve their intended learning goals if: (1) they are designed with clear learning outcomes in mind, (2) they are thoughtfully sequenced into the flow of classroom science instruction, (3) they are designed to integrate learning science content with learning about the processes of science, and (4) they incorporate ongoing student reflection and discussion. (NRC, 2006, p. 6)

Research about the typical style of laboratory work where students participate in laboratory experiences which are separated from the content shows students' misconceptions remain intact (Champagne, Gunstone, & Klopfer, 1985; Dupin & Joshua, 1987; Linn, 1997; Van den Berg, Katu, & Lunetta, 1994). When laboratory activities are integrated within the curriculum, as they are for IB, they facilitate students learning the material (Dupin & Joshua, 1987; White & Gunstone, 1992). Wells, Hestenes, and Swackhamer (1995) and White (1993) found that there was enhancement of Newtonian mechanics understanding when using integrated units. Other physics and chemistry topics that showed similar results include electricity (Shaffer & McDermott, 1992); matter (Lehrer, Schauble, Strom, & Pligge, 2001; Smith, Maclin, Grosslight, & Davis, 1997; Snir, Smith, & Raz, 2003); thermodynamics (Songer & Linn, 1991); and stoichiometry (Lynch, 2004). Topics investigated in biology include genetics (Hickey, Kindfield, Horwitz, & Christie, 2003) and natural selection (Reiser, Tabak, Sandoval, Smith, Steinmuller, & Leone, 2001).

The choices of which TOK tenets are used and the degree they are incorporated in Group 4 teaching has previously not been studied. The TOK portion of IB has tenets which are similar to Nature of Science (NOS) when compared by a panel of NOS experts in the science education field. NOS is of prominent interest to science educators as they strive to help produce people who are scientifically literate. Both the *Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993) and the *National Science Education Standards* (NRC, 1996), as well as many individual state standards, include sections on nature of science. These standards include terminology such as science as inquiry, science and technology, history and nature of science (NRC, 1996), the scientific worldview, and the scientific enterprise (AAAS, 1993).

There is much autonomy given to teachers in the IB program, allowing them freedom of choice in the types of activities and options they do with students or encourage students to do. At the present time when a new IB curricular cycle is being implemented, this study examined what choices Group 4 teachers make as they implement the new curriculum. This can provide information about the professional development needs of Group 4 teachers or the science education community as they prepare IB teachers. Thus it seems of interest to see what choices are being made and what resources are being used.

Do teachers choose areas of interest to them personally or are there other reasons? Are the topics deemed important by the science and science education communities the same topics chosen by IB Group 4 teachers? No reported studies have been conducted regarding the choices IB teachers make in these areas of curriculum and instruction.

This study is also needed to inform research on the choices IB Group 4 teachers make as they integrate laboratory work within the context of the rigorous IB curriculum. This will help to develop a better understanding of teacher choices in laboratory activities, resources teachers use, and the categories of student work expected for IB – IA. This information can then be utilized to help increase understanding of the complex nature of science education as it relates to teacher choice in IA.

When examining instruction, what teachers chose to teach in TOK and how their choices influence option topics and internal assessment will help develop a better understanding about IB science teachers and their instructional practices.

Assumptions of the Study

The following assumptions were made for this study:

1. The pilot study survey participants' comments improved the survey.
2. The panel of experts on the relationship between TOK and NOS were reliable and expressed comprehensive similarities and differences to inform the TOK tenets chosen.

3. All Reston, Virginia IB participants received a survey and had an opportunity to participate in the study.
4. Responses by survey participants were an expression of their actual choices.
5. Responding teachers accurately identified their reasons for choosing certain options, accurately gave the number of times activities were used, and listed all other activities utilized in their classrooms.

Limitations of the Study

Because the IB program includes schools in 125 countries around the world, this study is limited because it only included IB science teachers in North America who attended either a particular conference in Reston, Virginia or a roundtable discussion in Kansas City, Missouri. These teachers were chosen because they were primarily experienced IB science teachers as evidenced by their acceptance to a level 3 (higher level) IB training.

There are also other programs in North America which have rigorous curriculum with assessment components, such as the College Board’s Advanced Placement (AP) program. This limits the information on rigorous curriculum because only one curriculum was examined.

Data collection methods also limited this study. Since data were collected with a survey, direct communication with participants was limited. This did not allow for in-depth analysis of the participants’ thoughts and understanding or allow for complete understanding of what choices the teacher makes and how these choices are actually implemented in the teacher’s classroom.

Definition of Terms

Conclusion and Evaluation: This section of the IA is common to both the current and the 2009-2013 assessment cycles. It includes conclusions with justification and reasonable interpretation of data, evaluation of procedure, and improvement suggestions for the investigation.

Data Collection and Processing: Starting in the 2009-2013 assessment cycle, this section of the IA will include recording raw data, processing raw data, and presenting processed data. Previously, this was two separate sections: Data Collection and Data Processing and Presentation.

Design: Starting in the 2009-2013 assessment cycle, this section of the IA will include defining a problem, controlling variables, and developing a method for collection of data. Formerly this one section was divided into two: Planning A – question, hypothesis, and variables and Planning B – experimental design.

Group 4 – Experimental Sciences Area: This area includes curriculum for high and standard levels in biology, chemistry, physics, design technology, environmental systems, and sports, exercise and health of the IB program.

High Level (HL): The level of IB curriculum in which students are expected to study topics in greater depth than SL. There are a total of 240 instruction hours, including IA, expected at this level.

Internal Assessment (IA) – Practical Scheme of Work (PSOW): This component includes investigations in a variety of forms including laboratory practicals or projects which may be short or extend over a longer period, computer simulations, data-gathering exercises, data-analysis exercises, fieldwork, etc.

Internal Assessment Categories: These are categories which include design, data collection and processing, and conclusion and evaluation by which students are evaluated in the IA portion of IB.

International Baccalaureate Diploma Program: "A challenging two year curriculum" where students "learn more than a collection of facts" but are encouraged to "ask challenging questions, learn how to learn, develop a strong sense of their own identity and culture, and develop the ability to communicate with and understand people from other countries and cultures" (International Baccalaureate, 2005-2007, Diploma, p. 1).

International Baccalaureate North America (IBNA): The IB region which includes Canada, the United States, and the Caribbean and is based in New York.

International Baccalaureate Organization (IBO): The governing body of IB based in Geneva, Switzerland.

Online Curriculum Center (OCC): A resource for IB teachers where they can examine changes, discuss issues related to curriculum and instruction with other IB teachers in their teaching area, and get resources provided by IB for teacher use, among other perks.

Options: Curriculum components in the IB program which allow for further in-depth study of a particular topic. Teachers at each level must choose two options that are available in the class's curriculum guide.

Standard Level (SL): Level of IB curriculum which studies the core syllabi, completes an IA scheme and completes two options. There are a total of 150 hours of instruction, including IA, expected at this level.

Teaching Experience: This describes the number of years the teacher has been involved in classroom instruction both within the IB program and in general including the 2007-2008 school year.

Theory of Knowledge (TOK): This component of IB expresses tenets specific to nature of science and science study. These include that

> There is not one scientific method, in the strict Popperian sense, of gaining knowledge, or finding explanations for the behavior of the natural world; science works through a variety of approaches to produce these explanations, but they all rely on data from observations and experiments and have a common underpinning rigour, whether using inductive or deductive reasoning; the explanation may be in the form of a theory, sometimes requiring a model that contains elements not directly observable. Producing these theories often requires an imaginative creative leap; where such a predictive theoretical model is not possible, the explanation may consist of identifying a correlation between a factor and an outcome. This correlation may then give rise to a causal mechanism that can be experimentally tested, leading to an improved explanation; all these explanations require an understanding of the limitations of data, and the extent and limitations of data, and the extent and limitations of our knowledge; science requires freedom of thought and open-mindedness, and an essential part of the process of science is the way the international science community subjects the findings of scientists to intense critical scrutiny through the repetition of experiments and the peer review of results in scientific journals and at conferences. (International Baccalaureate Organization, 2007, p. 4)

Summary

This chapter includes an introduction that explains the study and background information about IBO and IB Group 4-science. Following this are statements of the need for this study, lists of the assumptions and limitations, and definitions of the terms used in this study.

Chapter II is the literature review which supports this study and related research on the topics identified. In Chapter III, the research design and methods are explained.

Chapter IV presents the analysis and interpretation of data. Concluding the dissertation in Chapter V is a summary of the study, a summary of the major findings, a conclusion, a discussion relating the study's findings to earlier research, and a series of recommendations for future research.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

A review of the literature begins with rigor in curriculum as demonstrated in IB and AP programs of study and teacher standards for teaching in these rigorous courses. Teacher decision making was examined both generally and specifically as it relates to teaching in this rigorous curriculum, including making decisions about student laboratory experiences and their effectiveness for practical work, types of activities teachers choose, and resources teachers use. Also TOK tenets of the IB curriculum were analyzed. NOS research on teacher beliefs, understanding, and implementation was reviewed as they are aligned with TOK tenets.

Rigorous Curriculum – IB and AP Programs

Rigorous science curriculum has gained increased focus since the NCLB Act (2002) was signed into law. One component of the act is to provide for the improved academic achievement of students by encouraging educational entities to “develop more rigorous mathematics and science curricula that are aligned with challenging state and local content standards and with the standards expected for postsecondary study in engineering, mathematics, and science” (NCLB, 2002, p. 1643).

The National Research Council (NRC, 2002) suggested that science teachers expose students to more in-depth content in key subject areas by including multiple examples to reinforce major concepts with in-depth coverage of fewer topics. After examining IB and AP programs, an NRC panel found that “they are comprehensive but shallow” (Hoff, 2002, p. 2). Regardless of this claim, whenever rigorous curriculum is mentioned, IB and AP programs seem to be highlighted. In the case of AP one reason for this may be due to part of NCLB being the

Advanced Placement Act, where one of the stated purposes is to "build on the many benefits of advanced placement programs for students" (NCLB, 2001, p. 1606).

"Engaging students in more challenging coursework appears to boost learning and achievement" (Clemmitt, 2006, p. 1), is an example of dialogue from individuals involved in either the AP or IB programs. It acknowledges that much of what is known about the benefits of IB and AP is anecdotal or supplied by the individual organizations themselves, with limited research on determining the impact of these curricula.

A study by the National Research Council, "Learning and Understanding: Improving Advanced Study of Mathematics and Science in the U.S. Schools," examined AP and IB programs by focusing on questions about advanced study to gain "improved, research-based understanding of teaching and learning" (Gollub, Bertenthal, Labov, & Curtis, 2002, p. 1). No data were gathered for this study; they relied on materials and testimony from individuals who were officials of the two organizations, teachers for the two programs, or students in the two programs. There were two areas of emphasis in the study on the consistency of the programs: (a) research on cognition and learning and (b) availability of equal access to the advanced study programs. They found "frequent inconsistencies" (p. 2) with the programs and cognition and learning research, and limited access to these programs for minorities and students in inner-city and rural schools.

The National Center for Education Statistics, as part of the National Assessment of Educational Progress (NAEP) High School Transcripts Study (HSTS, 2005), showed "high school graduates who took neither AP/IB mathematics courses nor AP/IB science courses earned a lower overall mean GPA than the AP/IB course-taking subgroups" (Perkins, Kleiner, Roey, & Brown, 2004, p. 2). Sadler and Tai (2007) investigated whether it was better for students preparing for college to take an AP course and get a lower grade or take a "regular" course and get an A grade. They found when taking variations in college grading systems into account, there was "strong evidence to support adding bonus points to students' high school course grades in the sciences, namely, on a 4-point scale, 1 point for AP courses and .5 for honors courses" (p. 5). Colleges assume students' success in the advanced courses predicts success in college courses, especially in mathematics and science.

Achievement levels of students who participated in AP or IB programs have been examined in two empirical studies: "Testing Physics Achievement" (Pfeiffenberger, Zolanda, & Jones, 1991) and "An Empirical Study of the Achievement of International Baccalaureate Students in Biology, Chemistry and Physics – In Alberta" (Poelzer & Feldhusen, 1996). The Pfeiffenberger et al. study focused on the dynamics of writing tests for AP physics and examined data from NAEP and the International Assessment of Educational Progress (IAEP, 1988) on physics achievement. The discouraging news was that "student performance seldom meets the expectations of the test development committees" and there is a "low rate of participation among women and some minorities" (p. 37). Their study provided encouraging news as well: From 1956-1990 there was an increase in the number of students taking the AP exam but not a significant decrease in the scores on the examination. In the Poelzer and Feldhusen study, IB students in all science areas had higher achievement levels on pre and post tests administered than did non-IB students, with students in biology showing the greatest increased achievement.

There is much controversy regarding whether AP or IB courses truly affect persistence to college graduation or performance in college. Klopfenstein and Thomas (2005) stated, "Our findings suggest that while a rigorous high school curriculum clearly impacts the likelihood of early success in college, AP courses are not a necessary component of a rigorous curriculum" (p. 14). In contrast, Adelman (1999, 2006) concluded that a rigorous high school course load is a factor in college success, with AP courses being one factor that influenced completion of a bachelor's degree. He concluded that "taking at least three Carnegie Units in core laboratory science (biology, chemistry, and physics) is more critical than taking AP classes, even though AP courses contribute to the highest level of academic intensity in a high school curriculum" (2006, p. 2). Burris, Welner, Wiley, and Murphy (2007) conducted a telephone survey of students who had participated in the IB program, and students enrolled in IB English and mathematics were more likely than other students in the school to complete college in four years.

The only studies that have examined curriculum taught in high school classrooms have been sponsored by the AP and IB organizations are reported on their web sites. Recently, there was a concern that schools were offering curricula with the AP label and not the AP rigor; subsequently, the College Board initiated an audit where all AP teachers had to submit their curricula for review by an examiner. Only after the curriculum was determined to meet the standards set by AP was a school allowed to label its course as an AP course. This is one effort to preserve the rigor of AP courses and to let colleges and universities know that an AP course must meet certain standards (College Board, n.d.a).

Although discussion regarding rigorous curriculum tends to include both AP and IB, there are distinct differences. Mathews and Hill (2005) noted, "Unlike most AP courses, an IB course does not allow students to skip the final examination without penalty" (p. xii). They described the differences between the two examinations,

> An AP final examination is usually three hours long. Usually half of it is essay questions…But the other half is multiple-choice questions. These are machine scored. IB examinations are often five hours long and have fewer multiple-choice questions, often none at all. (p. 25)

Another major difference is the degree of challenge the two programs offer. Mathews and Hill (2005) stated,

> It is one thing for students to prepare for AP examinations in subjects they like and do well in. It is another kind of challenge to prepare for external examinations that cover an entire curriculum, integrate one's learning in the Theory of Knowledge course, write an extended essay and perform community service, (p. 102)

alluding to IB as the more challenging of the two programs.

According to Kyburg, Hertberg-Davis, and Callahan (2007), minority IB students believed their teachers knew them on a personal level and were “confident that their teachers possess expert knowledge in their fields” (p. 205). They thought the TOK component of the IB curriculum “especially encourages students to challenge conventional ways of approaching problems or thinking about things, and the required extended essay is one area where students have more latitude to choose topics of personal interest” (p. 205).

Teacher effects, standards, and qualifications in rigorous curriculum

“Individual teachers have substantial leeway in implementing AP and IB courses. Therefore, the nature and quality of instruction may vary considerably from classroom to classroom” (Gollub et al., 2002, p. 10). Studies conducted to probe the relationship between teacher behavior and student learning and achievement reported a definite relationship (Brophy, 1979; Burton, Whitman, & Yepes-Baraya, Cline, & Kim 2002; Haycock, 1998; Wenglinsky, 2002; Wright, Horn, & Sanders, 1997). Kyburg et al. (2007) listed two key factors which contributed to minority students’ academic growth. One of these was teachers providing “scaffolding to support and challenge students” (p. 173). This support included time spent with students before and after school, lunchtime discussion groups, and college visits subsidized by the school. Because “differences in teacher effectiveness were found to be the dominant factor affecting student academic gain” (Wright et al., 1997, p. 66), examining the research on teacher quality in the IB and AP programs is important.

IBO “views its teachers as essential to the success of the school learning community” (IBO, 2005-2007, p. 1). It provides professional development through the online curriculum center (OCC) and professional workshops and conferences conducted yearly in each region. Yet the IB literature fails to identify qualifications for IB teachers.

While AP has a publication that outlines standards for teachers in the program (College Board, 2005), there is no system in place to check if these standards are met in individual schools except standards set by individual districts, communities or states. These standards are divided into the following five categories: "(1) content knowledge, (2) teacher certification, (3) pedagogy and student learning, (4) analysis and practice, and (5) ongoing professional development" (p. 2). These recommendations include that teachers should have at least a bachelor's degree in their subject area or subject area education. Several studies are cited which promote teacher expertise as supporting student achievement (National Commission on Teaching & America's Future, 1996; Ferguson, 1991; Darling-Hammond, Berry, & Thorensen, 2001a; Darling-Hammond, 2001b; Wenglinsky, 2002). The AP document provides recommendations, but there are no reports on whether individual schools meet these recommendations.

Milewski and Gillie (2002) surveyed AP teachers to determine their characteristics and needs. Their survey included sections on classroom characteristics, teacher background, professional development, and training and resource needs. Their conclusions were: most survey respondents expose their students to many different kinds of "nontraditional" (p. 7) educational materials; mathematics and computer science, physical/natural science, and social science teachers are more likely to have a bachelor's degree in a matching academic discipline; "the distribution of teachers across types of teaching certification status showed that AP teachers are well trained and prepared to teach AP courses" (p. 12); and teachers need training in managing time to teach the "breadth of AP coursework, prepare students for AP examinations and methods for teaching difficult material" (p. 14).

Teacher Decision Making

Several general factors affecting teachers' decisions have been investigated regarding their impact on the implementation of innovative curriculum and practice. Doyle and Ponder

(1977-78) stated that “if one listens carefully to the way teachers talk..., it soon becomes clear that the term ‘practical’ is used frequently and consistently to label statements about classroom practices” (p. 2). Only content deemed practical will likely be incorporated into classroom procedures and instruction, even if it is considered innovative by the person or group promoting it. To make decisions about practicality, teachers seem to use three criteria: instrumentality, congruence, and cost.

Yinger (1979) proposed from his study of a combined first and second grade teacher’s planning and decision making that routines “played a major role in classroom organization and in this teacher’s thinking and planning for instruction” (p. 165). These routines included activity, instructional, management, and executive planning routines. These routines were seen to serve to “increase predictability and reduce the complexity of the teaching environment” (p. 165) as they played a major role in the decisions the teacher made in selection, organization, and sequencing of instruction. When these routines had been established, teachers were free to be more flexible because planning time was less when some decisions had been made already in the establishment of the routines. Textbook teaching was described as having a major influence on establishing routines and planning and could “eliminate the need for preactive planning in some classrooms” (p. 168).

Schmidt, Porter, Floden, Freeman, and Schwille (1987) identified several factors elementary teachers consider when they make content decisions. These include

> the teacher’s own beliefs about the subject matter, previous educational experiences, formal policies such as district objectives and tests, external influences apart from formal policies (e.g., other teachers, textbooks, and parents), characteristics of students, and the inter-relationship of different subject matters in the curriculum. (p. 441)

Their study, using a case study and interview approach, examined nine of the external factors which affect teachers when they make content decisions: textbooks, parents, other teachers, district objectives, tests, students, subject matters, experiences, and teacher conceptions. They concluded that “textbooks had a noticeable impact on most of the teachers’ content decisions; in fact this factor had the largest impact of the nine” (p. 454). Parents had no effect on content decisions. Even district objectives seemed to have limited effects; one participant responded: “No one has even mentioned it (district objectives) to me other than it is in the drawer…I’ve never really looked at them, to be honest with you” (p. 447). Similar comments were made regarding tests about which the teachers did not have knowledge of the test items. This proved to limit the influence of the test on teachers’ content decisions. An additional factor which influenced teachers’ content decisions was other teachers “in terms of a collective sense of what other teachers expected” (p. 445). It should be noted that this study was conducted prior to the accountability movement currently influencing American education, such as the National Science Education Standards (1996) and NCLB (2002).

Today, “Educators have articulated with increasing regularity and clarity that decisions in teaching, assessment, and selection of curriculum resources should be driven by the learning outcomes sought for students” (Lunetta, Hofstein, & Clough, 2007, p. 401). Weiss and Paisley (2004) noted from their study, *Looking Inside the Classroom: A study of K-12 mathematics and science education in the United States* that teachers

> cited state- or district-level curriculum standards, textbooks and curriculum programs selected at the district level, and accountability systems related to student achievement as influences on their decisions about what to teach. For many teachers, pressure for their students to do well on high stakes testing drove their selection of topics. (p. 27)

Weis, Pasley, Smith, Banilower, and Heck (2003) identified factors which influenced teachers’ planning of lessons included not only the ones quoted above but also “teachers’ familiarity with specific content and pedagogy; their perceptions of the needs of the students; and the views of the principal, parents or other key stakeholders” (p. 75).

Studies have been conducted comparing teachers with different experience levels to compare the ways they make decisions. Westerman (1991) examined the differences between the way expert and novice teachers plan for instruction. She found:

> Experts thought about learning as a sequential process, and they made planning decisions on the basis of related content knowledge that their students had been exposed to and could be expected to have retained…This cognitive analysis, along with the teacher's knowledge about her students' abilities, learning styles, interests, and motivations, formed the basis for her planning…Novice teachers, on the other hand, did not have enough knowledge about the overall curriculum nor sufficient awareness of student characteristics to allow them to perform an adequate cognitive analysis of the lessons they were planning. (p. 296)

Similarly, Henry (1994) used the Method Acceptance Scale for Teachers (MAST) survey instrument to study if there were differences in teachers at different stages in their pedagogical development with regard to their instructional decision making. She used Berliner's Pedagogical Development Stages (Berliner, 1987, 1988) to compare different groups of teachers. The stages included novice, advanced beginner, competent, proficient, and expert, with each stage having a description of the characteristics a teacher in that group had related to his or her decision-making schemes. The MAST survey includes several criteria for making decisions: formal student outcomes; informal student outcomes; teacher enjoyment; teacher compatibility; career enhancement; approval from principals, peers, school boards; colleague support; fate control; and concept reputation. In Henry's (1994) study, the most relevant factors reported by inservice groups regardless of grade levels were informal student outcomes, teacher compatibility, and teacher enjoyment. For preservice teachers, career enhancement was the only category considered relevant when making instructional decisions.

In a separate investigation, Henry (1994) compared two groups: one she called expert teachers and another which had 15 or more years of experience but she did not consider experts. She defined experts as teachers who "are not concerned with making instructional decisions based upon how much the administration, community, or school board will approve; on colleague support for the strategy or curriculum; or how much the decision will enhance their careers" (p. 10). Instead, she asserted, they are more concerned about "student enjoyment while learning and the compatibility of the instruction to their own philosophy and experiences of success in the classroom in the past" (p. 10). She reported that expert teachers' decision making tends to be more centered within themselves. In contrast, those teachers she described as non-experts tended to be more concerned about public image and administrative, community and colleague approval.

Deemer (2004) determined that school culture was an important determinant when teachers make decisions. She concluded that "teachers who feel more confident about their teaching capabilities are more likely to believe that intelligence is malleable" (p. 87). Teachers who were working in an environment which was not competitive but was a supportive culture were more likely to "provide students with meaningful, challenging and creative work that promotes learning" (p. 86). Kyburg et al. (2007) found that teachers in urban schools where minority groups are the majority "recognized the diversity and complexity of their students' backgrounds and were cognizant of potential limitations…demonstrated an ability to modify their instructional strategies to accommodate varying learning styles, interests, and levels of preexisting knowledge" (p. 203). They also noted that teachers tended to make decisions based on the whole class and more minority students tended to drop out of rigorous programs like AP and IB.

Burris et al. (2007) investigated the impact of encouraging more students of all ability levels to enroll in IB classes had on teachers' curricular decisions. They found when teachers focused instructional decisions on depth rather than breadth and broke long-term assignments down into component parts, all students achieved at higher levels.

Putnam (1984) and Ingram et al. (2004) examined how teacher decisions are data driven. Putnam's (1984) case study of one first and second grade teacher found that the teacher used a six-phase decision model which included making decisions concerning long-term outcomes and then using these long-term outcomes as a basis for short-term preactive and interactive curriculum planning and management decisions. During the preactive and interactive phases of instruction, the teacher was constantly collecting and analyzing student data which informed her decisions. This data collection and synthesis model was used throughout the year as the teacher planned each unit of study. Ingram et al. (2004) examined nine high schools known for being concerned with continuous improvement. The researchers expected that the schools would have "strong values and beliefs about the necessity of using systematic data to make decisions" (p. 1267). Instead, they found a sizable portion of the teachers used anecdotal information, experience, and intuition to make decisions. Approximately 15% of the population of teachers used both systematic and nonsystematic data to make decisions. Some of the reasons given for why data was not used to inform decisions were mistrust of the data, measurement challenges, and lack of time.

Decision making among high school science teachers was examined by Aikenhead (1984). He stated, "Teachers appeared to make decisions within a framework which holistically integrated science content and practical classroom knowledge – a knowledge that includes the basic beliefs of the teacher and the socialization of students" (p. 167). He focused on how science knowledge is used to meet socialization demands of the schools. He found that "in planning for instruction, a science teacher may draw upon several kinds of instructional resources such as last year's lesson plans, texts, university notes, reference books, packages, professional literature, examinations, audio-visual materials, and his or her own experiences" (p. 168). These resources prepared teachers for making holistic decisions while integrating science content with practical knowledge and still staying true to their basic beliefs. He noted that teachers "created a stable and reliable set of theories-in-use for pre-active decision making, a robust framework resilient to influences of curriculum innovators and education researchers" (p. 184).

Recently, Jones and Carter (2007) compiled research on science teachers' attitudes and beliefs. They defined attitudes and beliefs, but they also gave historical context to studies about attitudes and beliefs and described how teachers' epistemologies were affected by them. They concluded that "science teachers' attitudes are strongly influenced by epistemological beliefs…which include beliefs about science, beliefs about science teaching, and beliefs about learning science" (p. 1075). All of these contributed to the teachers' teaching paradigm, including the instructional behaviors used in the classroom. Pajares (1992) discovered that "beliefs teachers hold influence their perceptions and judgments, which, in turn, affect their behavior in classrooms" (p. 307). Numerous studies (Hashweh, 1996; Richmond & Anderson, 2003; Zipf & Harrison, 2003) confirmed this conclusion.

In contrast, Nehm and Schonfeld (2007) studied biology teachers who after a 14- week course in evolution to "address documented misconceptions identified by a precourse instrument" (p. 699) did not devote increased time to the teaching of evolution. These teachers gained knowledge about evolution and the nature of science and their misconceptions were decreased, but many of them still "preferred that antievolutionary ideas be taught in school" (p. 699).

Not only epistemological beliefs but other beliefs also influence the decisions teachers make. "A teacher's religious beliefs as well as the cultural beliefs of the society affect how instruction is framed and interpreted" (Jones & Carter, 2007, p. 1093). Haidar (1999) discussed how Islamic beliefs affected a teacher's practice and asserted that constructivist methodology fits well with Islamic views of how to study the world.

Science teachers' prior experiences have also been shown to affect their decisions (Skamp, 2001; Smith, 2003; Stuart & Thurlow, 2000). Aikenhead (1984) found that basic beliefs seemed to have been defined by the teacher's "university science experiences" (p. 184). The level of experience was also found to affect science teachers' decisions. Jones and Carter (2007) stated, "Novice teachers make instructional decisions for their students based on their own needs and not their students' needs" (p. 1082). Peacock and Gates (2000) and Lotter (2003) reported similar findings. One factor contributing to this was "lack of knowledge and skills needed to implement a preferred practice" (Jones & Carter, 2007, p. 1086). Jones and Carter (2007) further pointed out that "research suggests that teachers with more science content knowledge spend more time teaching science" (p. 1087).

Teachers' decisions also are affected by what information they consider their students will need to make decisions regarding their future. Jones and Carter (2007) noted that "the teaching of controversial issues is one way that teachers promote democratic participation and social justice" (p. 1090). As a result they may include topics like global warming or deforestation which have political and economic importance in the world today (Cross & Price, 1996).

Internal Assessment Laboratory Activities

The National Research Council's *America's Lab Report* (2006) examined the current state of laboratory experiences, how they are used in classrooms, and how effective are different approaches. The report stated, "Research focused on the goal of student mastery of subject matter indicates that typical laboratory experiences are no more or less effective than other forms of science instruction (such as reading, lectures, or discussion)" (NRC, 2006, p. 5). This was partially based upon research findings from Blosser (1983), who reported that the majority of the quantitative studies comparing laboratory work and other teaching methods showed no significant differences. Some science teachers have abandoned laboratory experiences because they do not consider them necessary (Hawkes, 2004).

Regardless, laboratory experiences are a major component of rigorous IB programs. The IB program requires internal assessment which includes hours of practical work by the IB student. This PSOW is assessed by the teachers and monitored externally by examiners from IBO. This practical work that is deemed appropriate by the teacher, including laboratory investigations, "cookbook" labs, guided inquiry, open inquiry, database analysis, computer labs, or any practical work the teacher decides to incorporate into the curriculum. IB program requires that in at least two of the above activities students must complete all of the internal assessment components: design, data collection and processing, and conclusion and evaluation. In requiring these activities, IB seems to agree with Lunetta et al. (2007): "The school science laboratory is a unique resource that can enhance students' interest, knowledge of science concepts and procedures, and knowledge of important tools and skills that can develop new understanding" (p. 394). According to Duschl (n.d.a.),

> Science education has gone from science education for scientists to science education for all; from teaching what we know to teaching a way of knowing; from emphasizing content and process goals to goals examining the relationship between evidence and explanations; from an emphasis on science lessons that demonstrate concepts to lessons that promote reasoning about concepts; from topics that examine current science thinking to topics that examine science in social contexts; from science that emphasizes observation to a view that stresses theory and revision; from a view of scientific evidence relying on sense perception observations to evidence obtained from theory-driven observation. (p. 6)

Many of these changes would not be possible without the techniques, skills, and practices gained from scientific inquiry and laboratory work; these are also the techniques, topics and skills promoted by IBO.

Science as inquiry is one of the major strands in both of the most recent standards documents, *National Science Education Standards* (NSES; NRC, 1996) and *Benchmarks for Science Literacy* (AAAS, 1993). However, scientific inquiry has several definitions (Barrow, 2006). Inquiry done by the learner is identified in NSES to be an active learning process – "something that students do, not something done to them" (NRC, 1996, p. 2).

Inquiry can also be seen as a "central strategy for teaching science" (NRC, 1996, p. 31) or "inquiry teaching" (Anderson, 2002, p. 2). Anderson expressed a dilemma regarding the synthesis of research on inquiry teaching:

> Making generalizations about it (inquiry teaching) is difficult because of varied conceptions of inquiry teaching. This broad category includes such a wide variety of approaches that the label is relatively nonspecific and vague. Explicit descriptions of teaching practice help, but when various researchers are studying somewhat dissimilar teaching approaches, the generalization process still poses difficulties. (Anderson, 2002, p. 4)

Both inquiry done by the learner and inquiry teaching and are encouraged in the IB program.

Teachers' Decision Making for Internal Assessment

Teachers' decisions about content and pedagogy in laboratory programs are influenced by teachers' values, beliefs, and backgrounds. Carlsen (1991) focused on high school teachers' content knowledge and their teaching choices. He reported that teachers with more content knowledge tended to be "more likely to use whole-class instruction to present new material or review students work" and when teachers did not know the material well they "were more likely to use student-centered activities in which students had more opportunities to talk" (p. 646). He noted that this "does not demonstrate that high-knowledge teachers deliver better instruction than low-knowledge teachers. They lecture more, but this probably means that there are more opportunities for students to question the teacher in public" (p. 646). In a meta-analysis of 65 studies conducted in the U.S. from 1966-1975, Druva and Anderson (1983) found that the process skills students learned in laboratory activities were positively associated with the number of science courses the teacher had completed.

Kang and Wallace (2005) focused their research on high school teachers' actions during science laboratory activities because they considered "lab activities are central parts of knowledge construction in science and hence, an essential area for identifying epistemological beliefs underlying teaching actions" (p. 141). They found that teachers who had naïve epistemological beliefs considered knowledge to be a transmittable component and "they view lab activities as an extra to the main lesson, and they fail to see lab activities as opportunities for students to make meaning" (p. 143). Laboratory activities were used for verification. These teachers also tended to deliver information directly and used demonstrations like "show-and-tell" (p. 160). Even teachers with more sophisticated epistemological beliefs did not always demonstrate these beliefs in practice; they tended to be influenced by outside factors such as time limitations, management issues, and materials access and information which affected their practice (Barnett & Hodson, 2001; Lederman 1999; Yerrick, Pedersen, & Arnason, 1998).

Lunetta et al. (2007) summarized the research on how different learning theory organizers affect the decisions teachers make in laboratory instruction. These models included the learning cycle model (Karplus, 1977; Schneider & Renner, 1980), introducing conceptual conflict (Erickson, 1979; Nussbaum & Novick, 1982), the generative model (Osborne & Freyberg, 1985), and the 5-E model (Bybee, 1997). They concluded that "the effects of teaching models on learning can have important implications for how teachers should implement laboratory activities" (Lunetta et al, 2007, p. 404), but teachers need to know the skills and have the pedagogical understanding of the model in order to implement the model as an effective tool for science instruction in the laboratory.

Inquiry pedagogy was studied by Crawford (2000) as she examined "new roles for teachers" (p. 916). She determined that "(a) inquiry is situated in a context, (b) teachers need to embrace inquiry, (c) collaboration between teacher and students enhances inquiry, (d) teacher and students' roles are complex and changing, and (e) greater levels of teacher involvement are required by teachers than in traditional teaching" (p. 933). Therefore, the teacher's role is more demanding than that of a facilitator or guide.

"Teacher beliefs about students and learning, such as ability levels or the need for drill and practice, represent obstacles to inquiry-based instruction" (Keyes & Bryan, 2001, p. 635). Several research studies (Brickhouse, 1990; Cronin-Jones, 1991; Duschl & Wright, 1989; Gallagher, 1991; Hashweh, 1996; Nespor, 1987) provided evidence that teacher beliefs influence whether teachers incorporate inquiry into their curriculum. Part of the problem may be that teachers have conflicting beliefs regarding incorporating inquiry into their curriculum. Keys and Kang (2000) showed that teachers have both personal and cultural beliefs. In this context,

> Teachers hold personal beliefs that inquiry promotes the scientific thinking and learning autonomy they want for their students; yet, enacting inquiry is mediated by cultural beliefs, such as transmission and efficiency. These dual beliefs sets cause tension for teachers who are attempting to use inquiry-based instruction. (Keyes & Bryan, 2001, p. 636)

Zacharia (2003) examined high school teachers' attitudes towards inquiry-based experiments and the use of interactive computer simulations. Zacharia reported that a teacher's "beliefs affect attitudes, and these attitudes then affect intentions and behavior" (p. 812). This research was supported by Nespor's (1987) study of the role of teacher beliefs based upon "a body of field-based research on teacher thinking, the Teacher Belief Study" (p. 317); Pajares' (1992) study of the meaning researchers give to beliefs; Duschl and Wright's study (1989) examining the degree science teachers consider the nature of the subject matter in the decisions they make; and Wallace and Kang (2004) who examined how evident teachers' epistemological beliefs were in their practice.

Windschitl (2002) investigated whether secondary student teachers' use of inquiry was affected by their preservice experience with inquiry. He found that pre-service teachers who used inquiry during their student teaching were those who had experiences either as professional scientists or conducted science research, not individuals who had more authentic views of inquiry or had reflected on their own preservice inquiry project more deeply.

Songer, Lee, and Kam (2001) reported that urban high school teachers may want to incorporate inquiry but face many obstacles. They are confined by lack of space, lack of equipment and materials, inadequate preparation time, low levels of science content and computer knowledge, large class sizes, high levels of teacher and student mobility, lack of administrative support and unreliable internet connectivity. These barriers affect teachers' decisions about whether to implement inquiry in their classrooms and its resultant effectiveness.

Laboratory Activities in Internal Assessment

A recent NSTA position statement, "The Integral Role of Laboratory Investigations in Science Instruction," stated that these activities "should not be a rote exercise in which students are merely following directions, as though they were reading a cookbook, nor should they be a superfluous afterthought that is only tangentially related to the instructional sequence of content" (NSTA, 2007, p. 1). NSTA calls for laboratory investigations to have a definite purpose, focus on processes, incorporate student reflections, and allow students to develop safe and conscientious laboratory habits and procedures. According to NRC (2006) students are to be given opportunities to make observations and gather evidence, have experiences in the laboratory and field, understand measurement error, and have the skills to "aggregate, interpret, and present the resulting data" (p. 77). Both of these organizations see the need for students to have hands-on experiences so that they are experiencing more of the methods and procedures that scientists use and not just reading about them in their textbooks or listening to their teachers talk about them.

Hofstein and Lunetta (2004) also acknowledged the importance of laboratory investigations, but they cautioned that although

> laboratory investigations offer opportunities to connect science concepts and theories discussed in the classroom and textbooks with observations and phenomena and systems, laboratory inquiry alone is not sufficient to enable students to construct the complex understanding of the contemporary scientific community…When laboratory experiences are integrated with other metacognitive learning experiences such as 'predict-explain-observe-demonstrations' and when they incorporate the manipulation of ideas instead of simply materials and procedures, they can promote the learning of science. (p. 33)

Lazarowitz and Tamir (1994) listed several goals for science laboratories:

> To provide concrete experiences and ways to help students confront their misconceptions; to provide opportunities for data manipulation through use of computers; to provide opportunities for developing skills in logical thinking and organization, especially with respect to science, technology, and society (STS) issues; and to provide opportunities for building values, especially as they relate to the nature of science." (pp. 97-98)

Several studies have been conducted to examine how students are affected educationally by laboratory experience (Beasley, 1985; Bell, 2004; Coulter, 1966; Driver, 1995; Gardiner & Farregher, 1997; Hofstein & Lunetta, 2004; Lehman, 1989; Lunetta, 1998; Van den Berg, Katu, & Lunetta, 1994; White & Tisher, 1986). One of the first research studies done on laboratory work was done by Coulter (1966). In this study three groups of students were given pre and post tests on factual knowledge, scientific attitude, application of principles, reaction to teaching treatment, and critical thinking. One group experienced an inductive laboratory approach where they designed their own experiment about problems suggested by the teacher or those which had been previously discussed. The second group experienced an inductive demonstration approach where the experiment was demonstrated by the teacher, then students drew their own generalizations. The final group, the deductive laboratory group, was given a presentation about a "principle or generalization" (p.185) by the teacher and then asked to perform an activity to substantiate the claims of the teacher presentation. Coulter concluded that both inductive approaches were "as effective as the deductive approach in teaching facts, application of principles, and laboratory techniques and that they in no way detracted from students' ability to know facts and principles" (p. 185). Furthermore, the inductive approaches were more conducive to teaching cause and effect relationships, making judgments after examining evidence, and evaluation of arguments.

Beasley (1985) concluded that with chemistry students, laboratory performance can be improved substantially through planned "skill practice activities" (p. 573). These activities improved the accuracy and precision of measurements done by students. This practice did not rely solely on hands-on work in the laboratory. Mental practice also contributed to greater accuracy and precision. White and Tisher (1986) believed that “Almost as a matter of dogma, laboratory work has long been accepted as an integral and vital part of science teaching” (p. 880) at the high school level. Lehman (1989) examined the perceived advantages and disadvantages of laboratory work among chemistry teachers and students. Both teachers and students considered these sorts of activities to be advantageous for student learning, but they agreed that time was a factor; since laboratory experiences require considerable class time “teachers and students feel that laboratory activities are an add-on type of activity” (p. 513).

Van den Berg et al. (1994) examined the effectiveness of using hands-on experience for facilitating concept development about electrical circuits at the high school level. They found the hands-on activities were effective in learning relationships in electrical circuits, but the activities alone did not enable the students to develop a fully scientific model of circuits. According to Hofstein and Lunetta (2004), “It is vital to provide opportunities that encourage learners to ask questions, suggest hypotheses, and design investigations – minds-on as well as hands-on” (p. 32). Liu (2006) reported high school chemistry students learned gas laws better when hands-on activities were combined with computer modeling. Driver (1995) suggested that if we expect students’ understanding to change and be more scientific, then there needs to be an interaction with someone in authority, usually a teacher.

Regarding quantity of laboratory activities performed by students, Gardiner and Farregher (1997) found that qualitative laboratory activities with a confirmatory nature were being used by biology teachers in British Columbia in numbers that were fewer than required by the course outline. However, students performed well on laboratory-based questions on the provincial examination. Freedman (1997) reported that Grade 9 physical science students who participated in regularly scheduled laboratory activities achieved at a higher level and had a more positive attitude towards science than the control group. The number of activities these students performed did not have to be extensive. Lunetta (1998) noted, “When a student conducts a few authentic investigations carefully, more meaningful learning generally results than when a large number of laboratory activities are conducted superficially” (p. 256). To Hofstein and Lunetta (2004) it was important to “encourage learners to ask questions, suggest hypotheses, and design investigations – minds-on as well as hands-on” (p. 32) and that this should be done so that the purpose is explicitly stated by both teachers and students. Therefore, the emphasis is on quality, not quantity, of laboratory experiences. Lunetta et al. (2007) noted that “many science topics are not readily amendable to first-hand examination in the school laboratory” (p. 410) for various reasons including cost and safety.

Several researchers have reported that students regularly “performed school science experiments with very different purposes in mind than those perceived by their teachers. Students tended to perceive following the instructions or getting the right answer as the principle purpose of the school science task” (Lunetta, 1998, p. 250). Bell (2004) noted one purpose of laboratory experiences was to open avenues of social interaction and collaborations. While students are learning science concepts they also will “develop an understanding of how to conduct coordinated group work, how to communicate about ideas and negotiate shared understanding, how to manage division of labor and specialization, and how to aggregate and compare results” (pp. 12-13). Lazarowitz and Tamir (1994) believed laboratory work promotes the development of cognitive abilities such as problem solving, analysis, generalizing, critical thinking, applying, synthesizing, evaluating, decision-making and creativity” (p. 98). Lunetta et al. (2007) determined that

> Effective use of laboratory experiences, on the other hand, can help students and their teachers clarify the nature of science and how it differs from other ways of knowing. Informed and relevant discussions about the nature of science in the context of laboratory work can help students make sense of their laboratory experiences and better understand conceptual and procedural scientific knowledge. (p. 409)

Resources for Internal Assessment and Inquiry

Tamir and Lunetta (1981) noted that the laboratory handbook "plays a major role for most teachers and students in defining goals and procedures for laboratory activities" (p. 478). Germann, Haskins, and Auls (1996) determined that "while some manuals have made efforts to include a few science process skills, they seldom call upon students to use their knowledge and experience to pose questions, solve problems, investigate natural phenomenon, or construct answers or generalizations" (p. 475). They suggested that although laboratory manuals are primarily verification in nature, they could be used to promote inquiry by having students apply what they have learned in the activity to "help explain common everyday objects and events" (p. 496) or by pursuing repeated trials and analysis of results using learning cycle or guided inquiry practices.

Earlier, Herron (1971) examined two handbooks of laboratory exercises, PSSC Physics and BSCS Blue Version, and found that the majority of the activities did not contain inquiry practices. Other studies in physics (Lunetta & Tamir, 1979), chemistry (Furhman, Lunetta, & Novick, 1982; Domin, 1998), and biology (Lumpe & Scharmann, 1991) found that the laboratory manuals examined used highly structured activities of step-by-step details for students.

Tamir and Lunetta (1981) examined laboratory handbooks from biology, chemistry, and physics, and found that "only limited opportunities were provided in the selected curricula for higher level activities such as hypothesizing and testing those hypotheses or designing experiments and actually performing them" (p. 483). Their analysis showed that students were commonly asked to "work as technicians following explicit instructions and concentrating on the development of lower level skills" (p. 483).

Chinn and Malhotra (2002) analyzed 468 inquiry tasks found in nine upper elementary and middle school textbooks and 26 inquiry tasks developed by researchers. All of the tasks they analyzed were promoted to be inquiry in nature. They found that few of the simple textbook tasks contained authentic science components, whereas the tasks developed by researchers more often contained authentic science components.

Dechsri, Jones, and Heikkinen (1997) examined chemistry laboratory manuals and found that there was increased achievement in some areas, especially manipulative skills, in practical work when they contained “visual information-processing characteristics” (p. 901). Along with this increased achievement, students were more likely to have positive attitudes towards laboratory work.

Evaluation in Internal Assessment

Laboratory experiences are required to be assessed in the IB program. The NSES (NRC, 1996) encouraged teachers to use assessment as guides for planning curriculum. This included “formative assessment” which teachers engage in both formally and informally. Lunetta et al. (2007) stated, “For decades, science teachers have assessed their students’ performance in the laboratory via written lab reports completed during or after the laboratory activity” (p. 415). Bell (2004) noted, “Diagnostic, formative assessments embedded into the instructional sequences can be used to gauge students’ developing understanding and to promote students’ self-reflection on thinking and understanding of the inquiry process” (p. 16). Recently, formative assessment has become a focus in science education research, but “science teachers have reported that assessing students during laboratory activities is quite challenging…they do not have sufficient time or skills for evaluating when they also have multiple teaching, management and safety responsibilities” (Lunetta et al., 2007, p. 417).

Ruiz-Primo and Furtak (2007) defined “informal formative assessment practices (as) gathering information about students’ developing understanding during everyday whole class conversations” (p. 58). They found that these types of assessments are helpful to increase middle school student learning in inquiry classrooms.

Bennett's (2001) United Kingdom study evaluated having a visiting examiner conduct assessment of practical work in schools. This examiner scored the practical work of individual students and then interviewed the students for a brief time to determine success on practical work. She found that this form of assessment was a valid, reliable, economic way to assess practical work. Another benefit from the process was the increased professional development which happened for examiners and teachers.

Duschl and Gitomer (1997) proposed that assessment conversations are effective in helping middle school teachers assess student understanding of practical work. "Viewing assessment as intrinsic to the instructional process represents a position that, though discrepant with conventional practice, is highly consistent with the first principle of assessment – to make inferences about students that support useful decisions in educational contexts" (p. 39).

Lawrenz, Huffman, and Welch (2001) evaluated science achievement for high school students who had experienced a curriculum which was designed based on NSES reform. The students were given different forms of tests: multiple-choice, open-ended written, hands-on skilled and hands-on investigative. They found that the different formats of tests were more highly correlated for higher achieving students than they were for lower achieving students. However, lower achieving students did better with more hands-on and investigative tests. There were no gender differences on assessments between students. Caucasians and Asian-Americans scored higher on multiple choice tests while African-Americans and Hispanics scored higher on hands-on tests.

Stecher, Klein, Solano-Flores, McCaffrey, Robyn, and Shavelson (2000) examined acid/base performance tasks based upon their content, format, and level of inquiry. They found that similar tasks did not correlate as closely as tasks which were dissimilar. One reason noted for this was that the skills tested on performance events are more general skills where it does not matter about the form of assessment.

Surry and Roth (1999) studied whether student self-evaluation might affect assessment of open-ended performance projects. They suggested that along with formal and informal teacher evaluations, student self-evaluations can be beneficial.

The United Kingdom and Hong Kong have conducted extensive research regarding the use of practical work and/or inquiry in their science curriculum. Both of these countries have national curriculum with practical work components required (Bennett, 2001; Brown & Moore, 1996; Buchan & Welford, 1994; Cheung & Yip, 2004; Gott & Duggan, 2002; Gray & Sharp, 2001; Yung, 2001).

Hong Kong has a school-based assessment scheme for practical work in biology where Yung (2001) investigated three teachers' struggles with different fairness issues when using this new assessment. These fairness issues related to assessing students fairly, not jeopardizing students' chances to learn science, and not depriving students of an "all-around" education (p. 985). He found that a significant change is required in pedagogy when an assessment change occurs and that there is an increased need for professional development so teachers can address their personal issues of fairness. Cheung and Yip (2004) reported that as teachers became more experienced with the school-based assessment, their information and management concerns lessened.

Studies involving hands-on or inquiry activities in science classrooms have shown they help prepare students for standardized examinations (Chang & Mao, 1998; Kaiser, 1996; Stohr-Hunt, 1996). Conversely, Tretter and Jones (2003) found that when teachers used inquiry-based teaching, their students did not necessarily achieve at a higher level on a North Carolina standardized test. Additional positive effects were increased participation of students in class activities and higher class grades.

Brown and Moore (1996) found that although teacher assessment of practical work makes a valid contribution to assessments, performance on practical skills is strongly dependent upon which curricular area is being examined. Differences exist between biology, chemistry, and physics regarding the types and magnitude of practical skills. Gott and Duggan (2002) concluded that written tasks may not be assessing the actual ability that is thought to be measured.

Hofstein and Lunetta (2004) noted,

> In this era when standards and external tests of students' achievement are increasingly popular, it is naïve to think that students' and teachers' behavior and practices will shift toward inquiry and the development of meaningful practical knowledge until such outcomes become more visible in the tests that increasingly drive what teachers, parents, and students think is important, and thus what they choose to do. The policy makers who control the testing programs and those who prepare the tests must be part of more functional efforts to improve the effectiveness of school science. (p. 44)

The impact made by high-stakes standardized examinations has received a considerable amount of research recently due to the initiation of NCLB in 2001 and previously the standards initiative of the 1990's in all 50 states (Goertz & Duffy, 2003; Vogler, 2002, 2006). Vogler (2002) reported that Massachusetts teachers were increasing the number of open-ended, critical-thinking, and problem-solving questions on their assessment; using more scoring guides; and using fewer multiple-choice questions due to the requirements on their state assessment. In contrast, teachers in Tennessee, where students complete high school graduation examinations, more frequently were found to use teacher-centered practices and multiple-choice questions (Vogler, 2006). The differences between these two studies were because of their different emphases. The Massachusetts study examined the effect on teacher practice of releasing to the public students' scores on performance events. The Tennessee study focused on how teachers' practices were affected where the graduation examination is primarily multiple-choice questions.

Theory of Knowledge/Nature of Science in IB Science Curriculum

A separate TOK class is one of the required components for students in the IB curriculum framework. The purpose of this class is to "encourage critical thinking about knowledge itself, to try to help young people make sense of what they encounter" (IBO, 2006, p. 3). It gives students the opportunity to "step back from this relentless acquisition of new knowledge in order to consider knowledge issues" (IBO, 2006, p. 3). This is accomplished by student discussions about questions presented by the teacher in various areas of knowledge including mathematics, natural sciences, human science, etc. Students use various ways of knowing such as sense perceptions, language, reason, emotion, etc., to focus on these different questions.

In the IB science program guide (IBO, 2007), TOK's ways of knowing are seen to be encompassed by science because it is "driven by emotion, using sense perception, enhanced by technology and combined with reason, it communicates through language, principally the universal language of mathematics" (IBO, 2007, p. 4). Also, tenets set forth in the IB science guide express this nature of science espoused by IB and statements regarding the potential for activities in science to have moral, ethical, economic, and environmental implications.

Zemplen (2007) commented that TOK

> Explicitly tackles issues in the broader context of the history and philosophy of science (HPS), together with aspects on the nature of science (NOS) in a pronouncedly non-authoritarian and student-centered approach…As science teachers generally show reluctance to treat NOS issues and especially wider problems about science like socio-scientific issues (SSI), the course provides a safe-haven for such ideas without 'sacrificing' precious time from the other courses. At the same time, it facilitates and encourages other teachers explicitly to increase the presence of TOK relevant materials in the other courses. (pp. 168-9)

Inclusion of TOK objectives occurs within the curricula of the IB sciences.

Although Zemplen (2007) took issue with one of the textbooks used for TOK and its presentation of the relationship between critical thinking and science education, he "believes that

IBO has taken a step in the right direction by starting the TOK course" (p. 189). He elaborated on how the TOK class can assist science teachers when teaching NOS components to students.

Teachers' Nature of Science Conceptions

"One of the problems with the existing NOS standards is lack of standardization in focus and language" (McComas, 2008, n.p.a.). This statement captures the essence of comments made by other researchers (Koehler, 2005; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). Duschl, Hamilton, & Grandy (1990) noted,

> If we are to ask science teachers to teach explicit aspects of the NOS, it would seem both reasonable and timely that, as a community, we come to some agreement about those aspects of what a vulgarized account of science might be recognizing, that although any account may be partial or even in some respects naïve, it is better than no treatment at all. (p. 697)

Others opposed a fixed understanding (Elby & Hammer, 2001). They considered that different areas of science may have different definitions of tentativeness and that emphasizing the tentative nature of science may hold back science students in the laboratory from making decisions based upon data.

Certain NOS concepts have been agreed to and promoted. They include that "scientific knowledge is empirical, tentative, creative, subjective, and socially and culturally constructed" (Southerland et al., 2006, p. 876). Lederman (2007) asserted that science knowledge should include that students be able to differentiate between observation and inference and between scientific laws and theories; scientific knowledge involves "human imagination and creativity"; it is subjective and "theory-laden"; and it is practiced within a culture and never absolute or certain. Other key sources of NOS concepts include AAAS, (1993); Lederman (1992, 2007); McComas & Almazroa (1998); NRC, (1996); and Osborne et al. (2003).

McComas (In press) compiled a list of NOS concepts based upon examining NOS ideas found in NOS books for the general reader who may lack a science or science education background. These ideas include:

> Science produces, demands and relies on empirical evidence; B) Knowledge production in science shares many common factors and shared habits of mind, norms, logical thinking and methods such as careful observation and data recording, truthfulness in reporting, etc. In addition, the principle aspects of scientific methodology hold that: experiments are not the only route to knowledge; science uses both inductive reasoning and hypothetico-deductive testing; & there is no one step-wise scientific method; C) Scientific knowledge is tentative, durable and self-correcting; D) Laws and theories are related but distinct kinds of scientific knowledge. Hypotheses are special, but general kinds of scientific knowledge; E) Science has a creative component; F) Science has a subjective element. In other words, ideas and observations are 'theory-laden'; thus bias potentially plays both positive and negative roles in scientific investigation; G) There are historical, cultural, and social influences on the practice and direction of science; H) Science and technology impact each other, but they are not the same; and I) Science and its methods cannot answer all questions. In other words, there are limits on the kinds of questions that can be asked of science. (pp. 6-7)

NSTA (2000) in the preamble to its position statement asserted, "All those involved with science teaching and learning should have a common accurate view of the nature of science" (p. 1). To determine what influences teachers' views (conceptions), several instruments have been developed to assess these views. Those considered to be valid measures by the science education community (Lederman, 2007) range from one of the earliest and most used quantitative multiple choice instruments, *Test on Understanding Science* (TOUS) developed by Cooley and Klopfer (1961), to more current instruments which involve qualitative measures such as in the series of instruments, *Views of Nature of Science A-E (VNOS)* (Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick, & Lederman, 2000; Lederman & Khishfe, 2002; Lederman & Ko, 2004; Lederman & O'Malley, 1990). Regardless of the study or instrument used, most researchers (e.g. Behnke, 1961; Carey & Strauss, 1970; Kimball, 1968; Miller, 1963; Saunders, 2001) determined that teachers did not possess adequate NOS understanding (Liang, Chen, Chen, Kaya, Adams, Macklin, & Ebenezer, 2006).

Because both pre-service and in-service teachers' NOS understanding was judged inadequate, a line of research was developed that examined how this understanding could be or was affected by outside influences. Akindehin (1988) expressed the view that in order to help science teachers develop adequate conceptions of NOS, there must be explicit methods used. Scharmann and Harris (1992) tried to determine these effects by examining the influence of an NSF-sponsored, three-week summer institute. They concluded that the "philosophical" NOS conceptions were not changed, but the "applied" NOS conceptions were improved. Others have used explicit approaches to advancing teachers' NOS views which primarily included elements of the history and philosophy of science (Billeh & Hasan, 1975; Hodson, 1985; Klopfer, 1964; Lavach, 1969; Robinson, 1965; Rutherford, 1964). These studies met with some success in helping to improve science teachers' NOS conceptions.

More recently, Akerson, Abd-El-Khalick, and Lederman (2000) found that explicit attention to NOS did help improve teachers' understanding of NOS. Schwartz and Lederman (2002) studied two beginning teachers and found that the teacher with more extensive subject matter knowledge had a more adequate NOS understanding and was able to implement more NOS into his classroom. Schwartz, Lederman and Crawford (2004) examined how explicit NOS instruction through seminars and reflective journals, along with authentic research experience, could enhance pre-service secondary teachers' conceptions of NOS. The participants of this group commented that the reflective journal component had the most impact on their views. Abd-El-Khalick (2005) studied the impact of a philosophy of science course on NOS. His results showed that students who completed a philosophy of science course developed a more in-depth understanding of NOS than those who had a science methods course concurrently. Scharmann, Smith, James and Jensen (2005) used an explicit reflective approach to teach NOS in a secondary methods course and found it helped teachers learn NOS and be better prepared to explicitly teach NOS to their students.

Several studies have used conceptual change theory in investigating NOS learning for teachers (Posner, Strike, Hewson, & Gertzog, 1982; Abd-El-Khalick & Akerson, 2004; Southerland, Johnston, & Sowell, 2006). They found that learning dispositions such as the need for right answers and comfort with ambiguity played an important role in how teachers developed NOS ideas when they were taught explicitly. Regarding the impact of conceptual ecologies on teachers' NOS ideas, "Learners who have religious beliefs were capable of constructing a relatively sophisticated understanding of NOS" (Southerland et al., 2006, p. 33).

Lederman (2007) summarized this research by saying,

> science teachers do not possess adequate conceptions of NOS, irrespective of the instrument used to assess understanding; (b) techniques to improve teachers' conceptions have met with some success when they have included either historical aspects of scientific knowledge or direct explicit attention to NOS; and (c) academic background variables are not significantly related to teachers' conceptions of nature of science. (p. 36)

He commented that there were two assumptions underlying most of the research: teachers' understanding of NOS affected their students' conceptions and teachers' behavior and the classroom environment were "necessarily and directly" influenced by teachers' NOS conceptions (Lederman, 2007, p. 36). He goes on to state that the research does not necessarily support these assumptions.

Teachers' Decision Making for NOS

Two schools of thought have developed where the focus is whether teachers' NOS understanding affects their classroom practices and/or behavior. One says that it may (Brickhouse, 1989, 1990) while the other disagrees (Duschl & Wright, 1989; Lederman, 1999; Lederman & Zeidler, 1987). The two qualitative studies by Brickhouse (1989, 1990) showed that teachers with more classroom experience had views on science and technology which affected their classroom practice, but the teachers with less experience did not demonstrate this same affect. Duschl and Wright (1989) determined NOS components were not part of what helped urban science teachers in making instructional decisions. Lederman and Zeidler (1987) and Lederman (1999) investigated high school biology teachers and reported no connection. There was some evidence that the experienced teachers were exhibiting behavior which was consistent with their NOS views, but when these same teachers were interviewed they asserted they were not trying to teach NOS (Lederman, 1999).

Some of the reasons teachers give for not using NOS components in their classroom practice are: the pressure to cover content (Abd-El-Khalick et al., 1998; Duschl & Wright, 1989; Hodson, 1993); classroom management and organizational issues (Hodson, 1993; Lederman, 1995); concerns for student motivation and abilities (Abd-El-Khalick et al., 1998; Brickhouse & Bodner, 1992; Duschl & Wright, 1989; Lederman, 1995); institutional constraints (Brickhouse & Bodner, 1992); years of teaching experience (Brickhouse & Bodner, 1992; Lederman, 1995); and admitted lack of understanding by teachers and lack of resources for assessment (Abd-El-Khalick et al., 1998). Regardless of the difficulties associated with teaching NOS, it is still considered to be one of the most important set of concepts which needs to be taught to science students (AAAS, 1993; NRC, 1996, 2002).

Nature of Science Inquiry and NOS

Lederman (2007) noted that “individuals often conflate NOS with science processes or scientific inquiry” (p. 819). He acknowledged that these two constructs are related, but it is important to make a distinction between them. He considered inquiry as providing “foundational experiences” which help students to understand NOS, but that inquiry is more related to the collection and analysis of data and drawing conclusions promoted in current teaching reforms (AAAS, 1990, 1993; NRC, 1996). He viewed this conflation as plaguing NOS research, expressing that several studies were about inquiry rather than NOS.

Summary

The focus of this study was the choices a teacher makes in a rigorous program. This chapter focused on the two rigorous curricula, IB and AP, where teachers are allowed to make decisions regarding curriculum and instruction to see how they compare, what are their characteristics, what benefits they allow for students, what research says about their effectiveness, and what qualifications are expected for teachers in the programs. Generally teachers who spent time with students before and after school, had lunchtime discussion groups, etc., implemented activities which supported student success.

Previous research has shown various factors that affect the decisions teachers make in their classrooms, such as making decisions based on practicality, routine, using textbooks for support, and referring to previous educational experience, other teachers, or formal policies. Teachers were found to examine student outcomes and consider their own compatibility and enjoyment of curriculum and instruction before they made decisions about what to do in their classrooms.

Since the internal assessment of IB includes laboratory work and scientific inquiry at various levels, several factors affecting the decisions teachers make for laboratory work were discussed. These factors include teachers' knowledge of the material; their beliefs, both epistemological and religious; data about student learning; intuition; last year's lesson plans; professional literature; and the impact teachers feel the activity will have on students' learning. The resources frequently used by teachers for IA's, including laboratory handbooks and textbooks and their effectiveness for promoting science inquiry, were discussed. Assessment of laboratory experiences concentrated upon use of students' written laboratory reports, different formative assessment techniques, and different styles of test questions like multiple-choice, open-ended investigative questions or performance events to determine what students had learned in a laboratory program ended this section.

The TOK component has special interest to the IB science teacher because it has many similarities to NOS. There has been limited research about TOK, but NOS was shown to be an important curricular component. It was purported that NOS use would be increased in the classroom if teachers gain increased understanding, but it was found that there is a lack of clear definitions and understanding of NOS among teachers. Extraneous factors which are believed to affect teachers' use of NOS tenets in their instruction include the amount of subject matter knowledge the teachers have, the coursework the teachers have completed (e.g., having had a philosophy of science course), and their classroom experience. Classroom management issues and the availability of resources were also shown to have an effect. The chapter ended with a brief discussion of a concern expressed by one researcher regarding the confusion of NOS and science inquiry.

CHAPTER III

METHODOLOGY

Introduction

This chapter contains the research questions and the hypotheses, the design of the study, instruments, and analysis of data. The survey method was chosen to examine the choices IB science teachers make for curriculum and instruction. The population, the formation of the survey, pilot testing, and the determination of appropriate use of the TOK components as they relate to NOS tenets are described.

Research Questions and Hypotheses

Research Question 1: What options do IB science teachers choose?

Research Question 2: What reasons do IB science teachers give for their option choices?

Research Question 3: To what degree do IB science teachers' courses taught, years of experience (total and IB), level of education, undergraduate major, graduate major, school population, and percentage of students enrolled in IB affect their reasons for choosing certain options?

Ho 1: There are no significant relationships between the reasons for teachers' option choices and the science courses taught, years of experience (total and IB), level of education, undergraduate major, graduate major, school population, and percentage of students enrolled in IB.

Research Question 4: What curricular choices do IB science teachers make related to IA activities?

Research Question 5: What choices do IB science teachers make related to the IA resources they utilize?

Research Question 6: What choices do IB science teachers make regarding the level of use for the different categories of IA?

Research Question 7: To what degree do IB science teachers' courses taught, years of experience (total and IB), level of education, undergraduate major, graduate major, school population, and percentage of students enrolled in IB affect their Internal Assessment choices?

> Ho 2: There are no significant relationships between the IA choices made by IB science teachers and the teachers' science taught, years of experience (total and IB), level of education, undergraduate major, graduate major, school population, and percentage of students enrolled in IB.

Research Question 8: What choices do IB science teachers make regarding TOK tenets they teach?

Research Question 9: To what degree do IB science teachers' courses taught, years of experience (total and IB), level of education, undergraduate major, graduate major, school population, and percentage of students enrolled in IB affect the amount of time spent on TOK components?

> Ho 3: There are no significant relationships between the amount of time spent on TOK tenets and the IB science teachers' courses taught, years of experience (total and IB), level of education, undergraduate major, graduate major, school population, and percentage of students enrolled in IB.

Research Question 10: What are the relationships between the TOK tenets taught by IB science teachers and their IA choices?

> Ho 4: There are no significant relationships between the TOK tenets taught by IB science teachers and their IA choices.

Survey Design

A survey (Appendix B) was considered the best approach to quickly and easily reach many people in widely scattered areas (Van Dalen, 1966). Dillman (1991) noted that mail surveys are used extensively, "first because there is a much lower cost for completing them; second, procedures for mail surveys are often deemed simple enough that individuals and organizations conduct their own rather than relying upon survey research organizations" (p. 226). He identified an advantage of mailed surveys being their "ability to estimate quantitatively the distribution of a characteristic in a population, and to accomplish this by obtaining information from only a small portion of that population" (p. 226-27).

Schaefer and Dillman (1998) stated that "the cost and speed advantages of e-mail make it ideal for a first mode of contact in surveys" (p. 379). Since the IB science teachers in this study were located throughout North America, ease of reaching many of them in a timely fashion was essential. Participants in this study were given the choice as to whether they wanted the survey sent by regular mail or as an e-mail attachment. All 40 Reston participants preferred receiving and responding to their survey through e-mail. Eight (62%) of the Kansas City participants completed the survey at the roundtable discussion. The rest returned the survey electronically.

Schaefer and Dillman (1998) found that for the population of their study "comparable response rates can be obtained for regular response rates and electronic mailed surveys" (p. 385). In the case of electronic mail, they found that responses came more quickly, "a slightly lower item nonresponse was achieved, and more complete answers were given to an open-ended question" (p. 385). Mehta and Sivadas (1995) concluded that unsolicited e-mail surveys were unacceptable because people who receive these types of surveys are not likely to respond. In fact, when solicitation of participants has occurred, if the participants missed the notification or solicitation request, they were unlikely to respond.

Schaefer and Dillman (1998) also suggested that the time frame for electronic surveys can be compressed. Due to the limited time it takes to send an e-mail and get a reply, reminders can be sent days after the survey rather than weeks. Follow-up requests can be sent a week after the initial survey, much sooner than by regular mail.

Development of surveys relies on a clear idea of the information that needs to be collected (Berty, 1979). This survey was designed to ascertain information from IB science (biology, chemistry, and physics) teachers related to their IB curriculum in the areas of option choices, reasons for option choices, resources for IA, areas of emphasis for IA, types of IA activities, and the amount of coverage of TOK tenets. Items for the list of IA activities came from activities listed in various IBO publications including curriculum guides and from the National Survey of Science and Mathematics Education (Weiss, Banilower, McMahon, & Smith, 2001).

The survey included four major sections: I. Curriculum, II. Practical Work, III. TOK, and IV. Demographics (Appendix B). In section I, respondents were asked to check the options they used for the 2007-2008 and 2006-2007 school years. Each content area (biology, chemistry, and physics) had specific option choices listed. Participants identified the reasons they chose these options. Section II asked participants to record the number of times different activities on a list were used in their IA. They could also record additional activities not listed. This was repeated for the 2007-2008 school year. Subsequently, a scale allowed teachers to identify the number of times they used particular resources from a list. Section II ended with teachers identifying on a scale the frequency they used the different categories of IA. Section III of the survey asked respondents to identify on a scale the frequency of the TOK tenets used. In Section IV, the demographics section, teachers identified experience for both total teaching and IB teaching, undergraduate major, advanced degree, advanced degree major, type and size of school where they teach, percentage of students enrolled in IB at the school, and any further comments.

An initial survey was designed and then piloted with 12 individuals to determine whether the format and style of the survey were appropriate. Respondents made comments about improvements, areas where clarification was needed, or additions they would suggest. Of the 12 pilot surveys distributed, six were returned with suggested modifications. The survey was revised based upon suggestions from the pilot and suggestions made by the dissertation committee.

Surveys were e-mailed to IB science conference participants or given directly to roundtable attendees who agreed to participate in the study. In addition to the survey, a letter of introduction and suggested reply deadline were provided. Participants were given two weeks to return the survey. After those two weeks, a follow-up e-mail was sent to all non-respondents.

TOK Component of Survey

TOK tenets were formed from the curriculum guide for the IB TOK class that each IB student must complete as part of his or her educational experience. In order to ascertain whether the TOK tenets are NOS, a panel of NOS experts evaluated the TOK tenets based on the IB curriculum guide. Panelists examined the TOK components and rated whether they agreed or disagreed with NOS tenets presented. This survey was mailed electronically to ten national NOS experts.

The responses by seven respondents were tabulated. Revisions were made in the survey based upon the comments. The revisions included changing the verb from "has" to "may have" in the statements about moral and ethical implications, economic implications, and environmental implications.

The panel agreed that the majority of the other TOK statements matched NOS. If four or more respondents agreed, the tenets were considered NOS components. Two statements which the majority did not consider agreed with NOS were "Scientific study requires knowledge of and consistent use of technology" and "Scientific study has environmental implications." These items were deleted in the survey.

Population and Sample

Participants for this study are North American IB science teachers who attended an IB conference held in Reston, Virginia in April, 2007 or a roundtable discussion held in Kansas City, Missouri in January, 2008 where the changes in the IB curriculum were discussed. These participants were selected because of their commitment to IB science teaching and their interest in the changes expected in the IB science curriculum for the 2009-2013 assessment cycle. The Reston conference provided level 3 training for experienced IB teachers whose schools were accepted IB schools and who had participated in previous IB-sponsored teacher training. Teachers attending the Reston conference included 120 biology teachers, 90 chemistry teachers, and 79 physics teachers for a total of 264 participants. The executive secretary in personal correspondence stated that 25% of these were school administrators and directors who were not solicited leaving a total of 198 possible participants (Ross, personal communication, February 22, 2008)

Contact information for the Reston training participants was denied by IBNA; therefore, a letter (Appendix A) was sent to the head of professional development in the IBNA office in New York. This letter was forwarded electronically to all Group 4 participants in Reston by IBNA after the Internal Review Board (IRB) approved the study (Appendix A). The participants were asked to send their contact information to the researcher regarding their willingness to participate. Twenty-five of these emails were returned "undeliverable" reducing the number of participants to 173 who attended the Reston workshop.

Contact was then made with the participants via e-mail including a survey (Table 1). Participants were asked to complete the survey and return it via e-mail or regular mail. The first page of the survey was specific to each curricular area – biology, chemistry, or physics – where individual option choices were solicited. The remainder of the survey was identical for each subject area.

After a period of three weeks, a reminder e-mail was sent to those participants who had agreed to participate in the study but had not returned their surveys. During that same time period IBNA sent out another request for participants. At this time a letter (Appendix A) and the survey were included with the request for participation because IRB approval had been granted to contact participants directly.

More participants were solicited during an IB roundtable meeting in Kansas City, Missouri where the researcher led the chemistry roundtable discussion. Participants at this meeting were also experienced IB teachers in the three subject areas who came to Kansas City to discuss the changes which were occurring for the new curriculum cycle as part of regional professional development. These participants either completed the survey that day or returned it or mailed/e-mailed it at a later date. Participants at the roundtable discussion included twelve biology teachers, twelve chemistry teachers and three physics teachers. This provided for 200 possible participants when the two conferences were added together. Table 1 shows the final number of participants from each conference and the percent participation total.

Table 1

Summary of the Participants Delineated by Science Course Taught and Conference Attended

Course	*National Conference* <u>*Reston*</u>	*Regional Roundtable* <u>*Kansas City*</u>	*Total*	*Total % (N=200)*
Biology	20	5	25	12.5%
Chemistry	13	5	18	9.0%
Physics	7	3	10	5.0%
Total	40	13	53	26.5%

Data Analysis

Surveys were numerically coded and entered into an Excel spreadsheet. All data analysis was performed using SPSS version 11.5 for Windows. Results for the descriptive statistics portions of the survey were analyzed using univariate analyses in frequency distribution tables of results.

Research question 1 was analyzed using descriptive statistics to determine the observed frequencies for different option choices. The total number of times each option was chosen was tabulated and recorded in Microsoft Excel for each science content area: biology, chemistry, and physics. Percentages were then calculated.

Research question 2 was analyzed using content analysis to group different responses into categories. Patton (2002) stated, “Developing some manageable classification or coding scheme is the first step of analysis” (p. 463). He described this analysis as involving “identifying, coding, categorizing, classifying, and labeling the primary patterns in the data” (Patton, 2002, p. 463). After content analysis was performed, the three main categories were determined to be: (1) curriculum correlations and relevance; (2) student preparation for the future; and (3 interest, background, and resource availability. This third category included reasons related to teachers commenting about the ease of the option to teach, student interest, teacher interest and background, and the resources available for teaching, including time. After the teachers’ reasons were categorized and recorded as variables, descriptive statistics were used to compare the frequencies for each category.

Research questions 3, 7, 9, and 10 were analyzed using an index of linear correlation, Pearson’s product-moment correlation coefficient (Corston & Colman, 2003). This index includes levels of correlation between two variables as linear relationships. If the correlation coefficient is between 0 and .19 there is no relationship, between .2 and .39 there is a low relationship, between .4 and .69 a moderate relationship, and higher than .7 a strong relationship.

The closer to 1 or -1 the correlation value, the more closely related the two variables (Schweigert, 2006).

Research questions 3, 7, and 9 used a multiple linear regression analysis along with the correlation analysis. Multiple regression is "a statistical technique for analyzing the separate and joint influences of two or more independent variables, also called predictor variables, on a dependent variable" (Corston & Colman, 2003, p. 112).

Research questions 4, 5, 6, and 8 were analyzed using descriptive statistics regarding the choices IB science teachers make in IA's, IA resources, IA categories, and TOK tenets taught. This allowed for quantitative data about the choices IB science teachers make in curriculum and instruction.

As a result of extensive use of data involving correlations between multiple variables caution is required. This caution is necessary due to the likelihood of making Type I errors which is when the null hypothesis is rejected when it is actually true. Caution is required when making conclusions based on these statistics as a result.

Summary

This chapter outlined the research design and methods for this study. The research questions with hypotheses were presented with a description of the population sample. The survey pilot method was outlined and the method for validating TOK tenets as NOS by a panel of experts was explained. Concluding the chapter data analysis was described.

CHAPTER IV

RESULTS

Introduction

This quantitative study was designed to gather data about instructional choices of IB science teachers. Chapter IV is divided into five main sections: demographics information, analysis about the choices sample teachers made for options and their reasons, teachers' choices for IA's, teachers' choices regarding TOK tenets, and relationships between IA activities and TOK tenets. The chapter concludes with a summary.

Demographics

Demographic information was used to determine the factors which affected IB science teachers' choices for curriculum and instruction. Twenty-five (47%) respondents taught biology, 18 (35%) taught chemistry, and 10 (19%) taught physics (Table 2).

Table 2

Frequency and Percentage Comparison for Participants and Course Taught (N = 53)

Course					
Biology		Chemistry		Physics	
n	%	n	%	n	%
25	47	18	35	10	19

Twenty-nine (56.6%) teachers had less than the mean (15.8, SD = 15.8) total years of teaching experience. Twenty-six (50.0%) teachers had less than the mean (6.4, SD = 4.1) years IB teaching experience (Table 3).

Table 3

Frequency, Mean, Standard Deviation, and Ranges of Total and IB Years of Experience (*n*= 53)

Years Teaching Experience	Total		IB	
	n	%	n	%
1-5	6	11.3	27	50.0
6-10	13	24.5	17	32.7
11-15	11	20.7	8	15.4
16-20	11	20.7	1	1.9
21-25	4	7.5	--	--
26-30	5	9.4	--	--
> 30	3	5.6	--	--
M	15.8		6.4	
SD	8.6		4.1	

Forty-four teachers (Table 4) held a master's degree or higher (master's: *n* = 42, 79.2%; doctorate: *n* = 2, 3.8%). Forty-three (81.1%) teachers held an undergraduate major in a science field. Their graduate majors were in education for 26 (49.1%) teachers (Table 5).

Table 4

Frequency and Percentage of Teachers' Advanced Degree Earned (*n*= 53)

Bachelors		Masters		Doctorate	
n	%	*n*	%	*n*	%
9	17.0	42	79.2	2	3.8

Table 5

Frequency and Percentage of Teachers' Undergraduate and Graduate Majors (*n* = 53)

Major Area	Undergraduate Degree		Graduate Degree	
	n	%	n	%
Education	10	18.9	26	49.1
Science Field	43	81.1	15	28.3
Administration	--	--	5.	5.7

The mean for student population was 1688.2 (*SD* = 663.04) with 25 (47.2%) of sample teachers' schools having a population of more than 1500 but less than 2001 students (Table 6). The mean percentage for students (Table 7) enrolled in IB was 21.57% (*SD* = 22.74).

Table 6

Frequency, Percentages, Means, and Standard Deviations for Ranges of Total School Populations in the Sample (*n* = 52)

School Populations											
0-500		501-1000		1001-1500		1501-2000		2000+		*M*	*SD*
n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*		
3	5.7	4	7.5	10	18.9	25	47.2	10	18.8	1688.2	663.04

Table 7

Frequency, Mean, Standard Deviation, and Ranges of Percentages of Students Enrolled in IB Diploma Program (*n*= 48)

Percentage of Student Enrolled in IB											
0-5%		6-10%		11-20%		21-30%		30+%			
n	%	n	%	n	%	n	%	n	%	M	SD
13	27.0	9	17.8	10	20.8	10	20.8	7	14.6	21.57	22.74

Option Choices and Reasons

Teachers identified their option choices for both the 2006-2007 and the 2007-2008 school years. Their responses included two choices for each year, although some teachers marked more than two.

Teachers were asked to identify the reasons they chose these particular options. Most teachers wrote four reasons (*n* = 36, 67.9%), one reason for each option choice. Six (11.3%) teachers wrote more than four reasons and eleven (20.8%) teachers wrote fewer than four reasons. These reasons were tabulated and content analysis was done. Reasons were not divided by science content area.

Biology Option Choices

Evolution was chosen as one of the options by 25 (100 %) teachers for the 2007-2008 school year and 16 (64.0%) for the 2006-2007 school year. Ecology and conservation was chosen as an option by 16 (64%) teachers in 2007-2008 while twelve (48.0%) teachers chose this option in 2006-2007. The top four option choices were evolution; ecology and conservation;

neurobiology and conservation; and further human physiology for the 2007-2008 school year (Table 8).

Chemistry Option Choices

Environmental chemistry was chosen by eleven (61.1%) teachers for the 2007-2008 school year; only two (11.1%) teachers chose this option in 2006-2007. Ten (55.6%) teachers chose human biochemistry in 2007-2008 while seven (38.9%) chose this option for 2006-2007 (Table 9). Chemistry teachers showed more diversity of choice than biology teachers.

Physics Option Choices

Mechanics extension option was chosen by nine (90%) teachers for the 2007-2008 school year. In contrast, seven (70.0%) teachers chose the mechanics extension for the 2006-2007 school year. Optics was the second most frequently chosen option by six (60.0%) teachers in both 2006-2007 and 2007-2008. Five (50.0%) physics teachers chose astrophysics as an option for 2007-2008, while four (40.0%) teachers chose this option in 2006-2007 (Table 10).

Reasons for Option Choices

Content analysis of the reasons IB science teachers gave for their option choices consisted of reading the reasons multiple times and each time dividing them into groups where teachers used similar phrases to describe their reasons. When the content analysis was performed it was determined that their reasons fell into three main categories: (1) Curriculum correlations and relevance, (2) Student preparation for the future, and (3) Interest, Experience and Resource Availability (Table 11).

Table 8

Frequency and Percentage Summary of Options Chosen by IB Biology Teachers

(*n* =25)

Options	Options Published 2001 Choices 06-07 n	%	07-08 n	%	Options Published 2007 Choices 07-08 n	%	Total 07-08 n	%
Diet and Human Nutrition	1	4.0	1	4.0	0	0	1	4.0
Physiology of Exercise	0	0	0	0	0	0	0	0
Cells and Energy	3	12.0	2	8.0	2	8.0	4	16.0
Evolution	16	64.0	12	48.0	13	52.0	25	100.0
Neurobiology and Behavior	5	20.0	6	24.0	7	28.0	13	52.0
Applied Plant & Animal Science	2	8.0	2	8.0	NA	NA	2	8.0
Ecology and Conservation	12	48.0	5	20.0	11	44.0	16	64.0
Further Human Physiology	10	40.0	3	12.0	8	32.0	11	44.0
Microbes and Biotechnology	NA	NA	NA	NA	2	8.0	2	8.0

NA: Not available as option

Table 9

Frequency and Percentage Summary of Options Chosen by IB Chemistry Teachers (*n* = 18)

Options	Options Published 2001 Choices 06-07 n	06-07 %	07-08 n	07-08 %	Options Published 2007 Choices 07-08 n	07-08 %	Total 07-08 n	Total 07-08 %
Higher Physical Organic Chemistry	4	22.2	4	22.2	NA	NA	4	22.2
Medicine and Drugs	7	38.9	2	11.1	6	33.3	8	44.4
Human Biochemistry	7	38.9	4	22.2	6	33.3	10	55.6
Environmental Chemistry	2	11.1	6	33.3	5	27.8	11	61.1
Chemical Industries	0	0	0	0	NA	NA	0	0
Fuels and Energy	8	44.4	7	38.9	NA	NA	7	38.8
Modern Analytical Chemistry	1	5.6	1	5.6	2	11.1	3	16.7
Further Organic Chemistry	3	16.7	3	16.7	2	11.1	5	27.8
Food Chemistry	NA	NA	NA	NA	1	5.6	1	5.6
Chem. In Industry & Technology	NA	NA	NA	NA	1	5.6	1	5.6

NA: Not available as option

Table 10

Frequency and Percentage Summary of Options Chosen by IB Physics Teachers (*n* = 10)

	Options Published 2001 Choices				Options Published 2007 Choices		Total 07-08	
	06-07		07-08		07-08			
Options	*n*	%	*n*	%	*n*	%	*n*	%
Mechanics Extension	7	70.0	9	90.0	NA	NA	9	90.0
Quantum & Nuclear Physics	2	20.0	2	20.0	2	20.0	4	40.0
Energy Extension	1	10.0	4	40.0	NA	NA	4	40.0
Biomedical Physics	0	0	0	0	0	0	0	0
History & Development of Physics	2	20.0	1	10.0	NA	NA	1	10.0
Astrophysics	3	30.0	4	40.0	1	10.0	5	50.0
Relativity	2	20.0	2	20.0	2	20.0	4	40.0
Optics	6	60.0	6	60.0	NA	NA	6	60.0
Communication	NA	NA	NA	NA	0	0	0	0
Digital Technology	NA	NA	NA	NA	0	0	0	0
Particle Physics	NA	NA	NA	NA	2	20.0	2	20.0
Relativity & Particle Physics	NA	NA	NA	NA	3	30.0	3	30.0

NA: Not available as option

Most IB science teachers identified reasons for choosing particular options which were grounded in their own and their students' personal interests and backgrounds. Some of the reasons given ranged from "It's easy"; "I like it," and "Students enjoy it," to more concrete reasons like "Student interest in learning detail about the human body"; "Time is a factor so I have to use these (chemistry) options with objectives that most closely match what I do in my regular curriculum"; and "It's not equipment extensive." Although some teachers gave reasons in the Student preparation for the future category like "Many students planning on taking pre-med in college" and "It correlates well with the AP physics test," reasons in this category were given far less often than for the other categories. A more extensive list of reasons given by participants can be found in Appendix C.

Reasons associated with the category Interest, Experience, and Resource were given in 2006-2007 and 2007-2008 60 (48.0%) and 64 times (48.9%) respectively. Reasons which fit the curriculum correlations and relevance category were given 54 (43.2%) and 51 (38.9%) times respectively (Table 11).

Table 11

Frequency and Percentage Summary of Reasons for Option Choices in 06-07 and 07-08

	Reasons 06-07[a]		Reasons 07-08[b]	
Reason	n	%	n	%
Curriculum Correlations and Relevance	54	43.2	51	38.9
Student Preparation for the Future	11	8.8	16	12.2
Interest, Background, and Resource Availability	60	48.0	64	48.9

a where *n* = 125 b where *n* = 131

Data for relationships between teachers' reasons for option choices and their demographics was analyzed using SPSS Pearson's Product-Moment Correlation Coefficient analysis. There was one significant correlation when categories of teachers' reasons were compared to demographic variables. This occurred when the 2006-2007 reason category was student preparation for the future and the demographic variable was total school population. No significant correlations were found between reasons and demographics for 2007-2008 (Table 12).

Regression analysis was performed using SPSS. One significant relationship was shown when curriculum correlations and relevance was the dependent variable and the teacher's highest earned degree was the independent variable (p = .023). The linear regression models' assumptions were met. (Table 13)

Hypothesis 1 regarding significant relationship between IB science teachers' options choices and their demographics was not rejected in all cases except when student preparation for the future was compared to total school population. Curriculum correlations and relevance also had a significant relationship with highest earned degree (p = .023) leading to the rejection of the null hypothesis.

Internal Assessment

IA Activities

Table 14 summarizes the means and standard deviations for all teachers' IA activity use. Hands-on activities and worksheets had means of 23.11 (*SD* = 19.10) and 22.74 (*SD* = 26.18) respectively. Recording or presenting data had a mean of 15.41 (*SD* = 16.83) and graphical analysis had a mean of 10.79 (*SD* = 10.69). The mean for graph development averaged 9.72 (*SD* = 9.84), while students design experiments and data logging had similar means, 4.17 (*SD* = 3.05) and 4.15 (*SD* = 6.07) respectively. The IA activities which had the lowest level of use were field trips and collaboration with professionals with means of .90 (*SD* = 1.15) and .43 (*SD* = 1.15) respectively (Table 15). Figure 1 found in Appendix D summarizes the total number of times different IA's were used by IB science teachers.

Significant correlations were found between the science course taught and IA activities of data logging (.351), graph development (.323), student written investigations (.284), participation in field work (.302), literature research (.351), and spreadsheet analysis (.303). Years of experience showed significant correlation with IA activity collaboration with professionals (.291) and graduate major (.287) with IA activity record or present data (Table 15).

The significant relationships listed in Table 16 for linear regression were when science course taught was the independent variable and the IA activities data logging, graphical analysis, graph development, participation in field work, literature research, and spreadsheet analysis on the computer were dependent variables. Significant relationships were also shown between years of IB teaching experience and collaboration with professionals. Graduate major as an independent variable showed a significant relationship with the IA activity record and present data.

IA Resources

Each teacher identified the IA resources they used and the amount of time utilized. These levels included: Never; Rarely (1-6 IA's); Sometimes (7-12 IA's); and Often (more than 12 IA's). The mode of use, "Often," described the level of resource use for teacher designed resources, while IBO-OCC, published lab texts, commercial kits, and workshops or conventions were used "Rarely." For published textbooks and other teachers as resources "Sometimes" described the level of use (Table 17).

Table 12

Pearson's Product-Moment Correlation Coefficient I Reasons with Demographics

(*n*= 52, n^a = 48)

	Demographics							
Reason Category	Science Course	Total Years Exp.	IB Years Exp.	Under-grad. Major	Highest Earned Degree	Grad. Major	Total School Pop.	IB Enroll %[a]
O6-07								
Curriculum Correlations & Relevance	.044	-.025	.131	-.265	.077	.044	-.030	.199
Student Prep. For Future	-.064	.060	.136	-.079	-.106	.054	-.279*	.182
Ease, Interest, Background, & Resources	.193	-.105	.090	.004	.084	.122	.070	.014
O7-08								
Curriculum Correlations & Relevance	-.038	-.154	.030	-.206	.047	-.044	.113	.156
Student Prep. For Future	.061	.136	.165	-.093	-.265	-.005	-.256	.113
Ease, Interest, Background, & Resources	.262	-.082	.148	.025	.145	.029	.028	.028

p <.05

Table 13

Summary of Linear Regression Data When Reasons for Option Choices as the Dependent Variable and Demographic Information as the Independent Variable (*n*=52)

Dependent Variable Option Choice Reason	Independent Variable Demographic	R^2	*B*	*SE B*	*Beta*	*p*
Curriculum Correlations & Relevance	Highest earned degree	.105	-.618	.260	-.406	.023

Significant negative correlations were found between the IA resource use – published laboratory texts and commercial kits when compared with the science course taught. Use of published textbooks had significant negative correlation with years IB teaching experience (Table 18). Regression analysis with IA resources as the dependent variable and the various demographics as the independent variable revealed no relationships at the 05 level.

IA Categories

Science teachers recorded their frequency levels for the different IA categories. For the 2006-2007 school year choices these categories included: Planning A, Planning B, Data collection, Data Processing and Presentation and Conclusion and Evaluation. For the 2007-2008 school years these choices included: Design, Data Collection and Processing and Conclusion and Evaluation. IB teachers are expected to do a minimum of two activities in each of these categories during the total implementation of the course but may do more. Categories for frequency levels were: Minimum (2 IA's only), Rarely (3-6 IA's), Sometimes (7-12 IA's), and Often (more than 12 IA's). The category conclusion and evaluation was the same for both 2006-2007 and 2007-2008 so teachers responded only once for this category.

Table 14

Means and Standard Deviations for Times IA Activities Chosen by Sample Teachers (*n* = 52)

IA Activities for 2007-2008	*M*	*SD*
Database analysis (IA1)	2.06	4.57
Data logging (IA2)	4.15	6.07
Graphical analysis (IA3)	10.79	10.69
Graph development (IA4)	9.72	9.84
Simulations (IA5)	3.30	3.66
Hands-on activities (IA6)	23.11	19.10
Student written investigations (IA7)	8.74	10.37
Participation in field work (IA8)	1.64	3.84
Worksheets (IA9)	22.73	26.18
Literature research (IA10)	2.40	2.64
Model building (IA11)	2.06	3.22
Group projects (IA12)	4.09	5.26
Spreadsheet analysis on computer (IA13)	1.28	2.00
Record or present data (IA14)	15.41	16.83
Audio/visual presentations (IA15)	5.56	13.91
Students design experiment (IA16)	4.17	3.05
Collaboration with professionals (IA17)	.43	1.15
Field trips (IA18)	.90	1.13

Table 15

Pearson's Product-Moment Correlation IA Activities with Demographics (*n= 52; n[a]= 48*)

	Demographics							
IA Activity	Science Course	Total Years Exp.	IB Years Exp.	Under-grad. Major	Highest Earned Degree	Grad. Major	Total School Pop.	IB Enroll %[a]
IA1	-.105	-.056	-.012	.134	.017	-.044	.017	-.062
IA2	.351*	.061	.048	.164	.010	-.043	.130	-.235
IA3	-.269	-.037	.100	.036	.-.013	-.057	.162	-.120
IA4	.323*	-.015	.130	.144	.047	-.088	.186	-.089
IA5	-.188	-.099	.051	.147	-.014	-.007	.097	-.189
IA6	.007	.062	.204	.059	.024	-.170	-.120	.126
IA7	.284*	.203	.120	-.092	-.142	.103	.064	.013
IA8	.302*	-.070	.155	.043	-.122	.055	.000	.132
IA9	-.181	.197	.191	.092	-.073	.119	.097	-.044
IA10	.351*	-.017	.136	.018	-.052	-.013	.067	.021
IA11	-.056	-.249	-.147	.069	-.050	.007	.101	.006
IA12	.045	-.100	.016	.203	.081	-.087	-.045	-.064

Table 15 Continued

Pearson's Product-Moment Correlation I IA Activities with Demographics (*n*= 52; n^a= 48)

IA Activity	Science Course	Total Years Exp.	IB Years Exp.	Under-grad. Major	Highest Earned Degree	Grad. Major	Total School Pop.	IB Enroll %[a]
IA13	.303*	.022	.097	.093	-.074	-.078	-.035	.029
IA14	-.022	.032	.191	.104	.079	.287*	-.128	.196
IA15	-.196	-.042	.159	-.154	.091	.203	-.003	-.006
IA16	-.143	.037	.041	.054	.155	-.074	.100	.034
IA17	.120	.291*	-.151	.035	.057	-.072	.015	-.086
IA18	-.098	.119	-.142	-.014	.045	-.068	-.110	.011

*$p < .05$

The categories for data collection (2001), data processing and presentation (2001), data collection and processing (2007) and conclusion and evaluation (2001 & 2007) were used at the level "Sometimes" indicating these categories were used 7-12 times for IA's during 2007-2008 by the most teachers. "Minimum" was the most frequently chosen level of use for planning A (2001), planning B (2001), and design (2007), indicating these categories were used two times during the school year. The level "Never" was chosen by 12 teachers (22.6%) for the category, Design. This may be due to the fact that this category is new to the IB curriculum in 2007-2008 (Table 19).

Table 16

Linear Regression Data IA Activities as the Dependent Variable and Demographics as the Independent Variables (*n*= 52)

Dependent Variable IA Activity	Independent Variable Demographic	R^2	*B*	*SE B*	*Beta*	*p*
Data logging	Science course	.235	3.250	1.057	.403	.004
Graphical analysis		.100	-4.715	2.081	-.317	.028
Graph development		.124	-4.793	1.878	-.352	.014
Participation in field work		.103	-1.727	.750	-.322	.026
Literature research		.088	-.988	.470	-.296	.041
Spreadsheet analysis on a computer		.229	.841	.353	.313	.022
Collaboration with professionals	IB teaching experience	.156	-.080	.039	-.285	.046
Record & present data	Graduate major	.082	-4.338	2.027	-.287	.037

Table 17

Frequency and Percentage Levels of IA Resource Use (*n* = 53)

	Frequency Levels							
	Never		Rarely		Sometimes		*Often*	
IA Resources	*n*	%	*n*	%	*n*	%	*n*	%
IBO-OCC	9	17.0	34	64.2	6	11.3	4	7.5
Published texts	9	17.0	17	32.1	18	34.0	9	17.0
Published lab texts	9	17.0	23	43.4	21	39.6	0	0
Commercial kits	16	30.2	27	50.9	10	18.9	0	0
Teacher designed	2	3.8	11	20.8	18	34.0	22	41.5
Workshop/convention	11	20.8	28	52.8	12	22.6	2	3.8
Other teachers	4	7.5	18	34.0	21	39.6	10	18.9

Pearson's product moment showed correlations for IA category Conclusion and Evaluation with 2001 categories, Planning A, Planning B, Data Collection, and Data Processing and Presentation. Data Collection and Processing (2007) showed significance with 2001 categories Data Collection, Data Processing and Presentation, and Conclusion and Evaluation. The 2007 category Design had no significant correlations with other categories (Table 20).

Table 18
Pearson's Product-Moment Correlation Coefficient I IA Resources with Demographics (n=53, n^a=48)

	Demographic Variables							
IA Resources	Science Course	Total Year Exp.	IB Years Exp.	Highest Earned Degree	Under-graduate Major	Grad. Major	Total School Pop.	IB Enroll %[a]
IBO	.046	.085	-.174	-.024	-.004	-.012	-.035	.042
Pub. Text	-.266	.096	-.304*	.054	-.254	-.026	.027	-.061
Pub. Lab Text	-.407*	.005	-.082	.100	-.049	-.211	-.048	-.078
Com. Text	-.491*	-.068	-.149	.217	.061	-.237	.179	-.066
Teacher Design	.113	.189	-.065	-.013	-.038	-.105	.122	.037
Workshop/ Convention	-.084	.067	.052	.021	.060	-.079	.005	.076
Other Teachers	.014	-.120	-.141	-.099	.055	.149	.006	-.015

$*p<.05$

Pearson's product-moment correlations were found between 2001 IA category Planning B with years of IB experience (-.290) and 2001 IA category Data Collection with graduate major (-.280) (Table 21). Regression analysis with IA categories as the dependent variable and demographics as the independent variable revealed no relationships.

Table 19

Frequency and Percentage of the IA Categories' Levels Chosen From the 2001& 2007 Curriculum Guides in 2007-2008 (*n* = 53)

IA Category	Never *n*	Never %	*Minimum* *n*	*Minimum* %	*Rarely* *n*	*Rarely* %	*Sometimes* *n*	*Sometimes* %	*Often* *n*	*Often* %
2001										
Planning A	1	1.9	5	9.4	30	56.6	12	22.6	5	9.4
Planning B	1	1.9	5	9.4	30	56.6	13	24.5	3	7.5
Data Collection	4	7.5	2	3.8	4	7.5	16	30.2	27	50.9
Data Processing & Presentation	4	7.5	2	3.8	5	9.4	17	32.1	25	47.2
2007										
Design	12	22.6	5	9.4	28	52.8	6	11.3	2	3.8
Data Collection & Processing	6	11.3	2	3.8	4	7.5	17	32.1	24	45.3
2001& 2007										
Conclusion & Evaluation	0	0	3	5.7	10	18.9	17	32.1	5.	43.4

Table 20

Pearson's Product-Moment Correlation Coefficient I Relationships between Different IA Categories (*N* = 53)

2001 Categories	2007 Categories Design	Data Collection & Processing	2001 & 2007 Conclusion & Evaluation
Planning A	-.008	.229	.418**
Planning B	-.080	.197	.413**
Data Collection	-.133	.411**	.573**
Data Processing & Presentation	-.077	.366**	.592**
2001 & 2007 Conclusion & Evaluation	-.099	.522**	---

** p < .01

Hypothesis 2 regarding the relationships between IA choices and demographics was rejected when the science course taught and the IA activities for data logging, graph development, student written investigations, participation in field work, literature research, and spreadsheet analysis are compared. It was also rejected for years of experience and IA activity collaboration with professionals and when graduate major is compared with the IA activity record or present data (Table 15).

Table 21

Pearson's Product-Moment Correlation Coefficient I Different IA Categories and Demographics

(n = 53, n^a = 48)

	Demographic Variables							
IA Category	Science Course	Total Years Exp.	IB Years Exp.	Highest Earned Degree	Under-graduate Major	Grad. Major	Total School Pop.	IB Enroll %[a]
2001								
Planning A	-.126	.012	-.201	-.044	.044	-.022	-.002	-.209
Planning B	-.079	-.018	-.290*	.032	.034	-.128	.016	-.226
Data Collection	-.010	-.040	-.053	.059	-.050	-.280*	-.141	.139
Data Processing and Presentation	-.043	-.017	.031	-.101	.086	-.120	-.019	-.043
2007								
Design	-.007	-.024	.189	-.155	.206	.202	.000	-.027
Data Collection & Process	-.056	.147	.043	-.086	.015	.049	-.003	-.075
2001& 2007								
Conclusion & Evaluation	-.218	.004	-.097	-.013	.070	-.175	-.054	-.160

$*p < .05$

Regression analysis supports the rejection of the hypothesis 2 when the science course of the teacher is the independent variable and data logging, graphical analysis, graph development, participation in field work, literature research, and spreadsheet analysis on a computer are dependent variables. Collaboration with professionals as the dependent variable and IB teaching experience as the independent variable also supports rejection of the hypothesis 2. Also, when record and present data is the dependent variable and graduate major is the independent variable, the null hypothesis was rejected (Table 16).

When examining IA resources hypothesis 2 was rejected when science course is compared to published laboratory text and commercial kits which showed significant negative correlations. This significant negative correlation between published textbooks and years of IB teaching experience supported the rejection of hypothesis 2 in these areas (Table 18).

Correlations between 2001 IA category Planning B with years of IB experience and 2001 IA category Data Collection with graduate major supported rejection of hypothesis 2 (Table 21).

TOK

IB science teachers identified their level of TOK tenets' use in their instruction. These levels were: Never, Rarely (a few times a year), Sometimes (once or twice each topic or option), and Often (more than twice for each topic or option).

"Sometimes" was the mode for level of use in for the following TOK tenets: 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, and 15. Science relies on data was the only TOK tenet which had "Often" as its level of use. "Rarely" was chosen as the level of use by 27 (50.9%) teachers for the TOK tenet there is not one scientific method. Sixteen (30.2%) chose this level for the TOK tenet scientific reasoning can be in the form of a theory requiring a model. Eleven (20.8%) was the highest number of teachers who chose "Never" as the level of use for a TOK tenet. This TOK tenet was causal mechanisms can be tested experimentally (Table 22).

Table 22

Frequency and Percentage of the TOK Tenets' Level of Use (*n*=53)

TOK Tenets	Never		Rarely		Sometimes		Often	
	n	%	*n*	%	*n*	%	*n*	%
TOK 1-There is not one scientific method.	10	18.9	27	50.9	12	22.6	4	7.5
TOK 2-Science relies on data from observation.	4	7.5	5	9.4	18	34.0	26	49.1
TOK 3-Science is empirical in nature.	7	13.3	3	5.7	25	47.2	18	34.0
TOK 4-Science includes inductive and deductive reasoning.	6	11.3	14	26.4	23	43.4	10	18.9
TOK 5-Scientific reasoning can be in the form of a theory requiring a model.	9	17.0	16	30.2	22	41.5	6	11.3
TOK 6-Science involves creativity.	6	11.3	12	22.6	27	50.9	8	15.1
TOK 7-Science may involve correlations between a factor and an outcome.	5	9.4	10	18.9	25	47.2	13	24.5
TOK 8-Causal mechanisms can be tested experimentally.	11	20.8	20	37.7	14	26.4	8	15.1
TOK 9-Scientific explanations require an understanding of data limitations.	4	7.5	11	20.8	24	45.3	14	26.4
TOK 10-Science requires freedom of thought and open-mindedness.	6	11.3	13	24.5	21	39.6	13	24.5

Table 22 Continued

Frequency and Percentage of the TOK Tenets' Level of Use (*n*=53)

TOK Tenets	Never		Rarely		Sometimes		Often	
	n	%	*n*	%	*n*	%	*n*	%
TOK 11-Scientific study is subject to intense critical scrutiny.	6	11.3	17	32.1	21	39.6	5.	17.0
TOK 12-Scientific study requires knowledge of and consistent use of technology.	5	9.4	14	26.4	27	50.9	7	13.2
TOK 13-Scientific study may have moral and ethical implications.	4	7.5	11	20.8	25	47.2	13	24.5
TOK 14-Scientific study may have economic implications.	5	9.4	13	24.5	25	47.2	10	18.9
TOK 15-Scientific study may have environmental implications.	3	5.7	10	18.9	27	50.9	5.	24.5

Pearson's correlation analysis was performed between TOK tenets and demographics. Correlations which were significant were between the science course taught and TOK tenet science is empirical in nature (.368); teachers' total years of experience and years IB experience with the TOK tenet scientific study is subject to intense critical scrutiny with correlations .356, and .342 respectively (Table 23). Years of IB experience was also significant with the TOK tenet scientific explanations require an understanding of data limitations (.374). Table 23 also shows teachers' graduate major and TOK tenet science relies on data from observation was significant

(.372). Correlations which were significant were found between teachers' total years of experience and TOK tenet scientific study may have environmental implications (.311) and teachers' years of IB teaching experience and TOK tenet science is empirical in nature (.288). Teachers' graduate major correlated with the TOK tenets science involves creativity (.289) and science may involve correlations between a factor and an outcome (.281). Total school population correlated with science is empirical in nature (-.324) was a negative significant correlation (Table 23).

Linear regression analysis with the various TOK tenets as dependent variables and demographics as the independent variables showed a significant relationship for TOK tenet scientific study is subject to intense critical scrutiny and the demographic years total teaching experience (Table 24). The TOK tenet scientific study may have environmental implications as the dependent variable and total years of experience as the independent variable (p = .041) and years of IB experience as the independent variable with the TOK tenets science is empirical in nature (p = .037) and scientific explanations require an understanding of data limitations (p = .020) also showed significant relationship.

Due to the significant relationships described in Tables 23 and 24, hypothesis 3 regarding the relationships between TOK tenets and demographics was rejected for the science course taught with the TOK tenet science is empirical in nature; years IB experience with TOK tenet scientific study is subject to intense critical scrutiny; and teachers' graduate major and the TOK tenet science relies on data from observation.

In addition hypothesis 3 was rejected for teachers' total years of experience and the TOK tenets scientific study is subject to intense critical scrutiny and scientific study may have environmental implications. The relationship between years of IB experience with the TOK tenets science is empirical in nature and scientific explanations require an understanding of data limitations had both correlation and regression analysis; therefore, hypothesis 3 was rejected.

Table 23

Pearson's Product-Moment Correlation Coefficient I TOK Tenets and Demographics (*n*= 53, *n*[a] = 48)

	Demographics							
TOK Tenets	Science Course	Total Years Exp.	IB Years Exp.	Highest Earned Degree	Under-graduate Major	Grad. Major	Total School Pop.	IB Enroll %[a]
TOK 1	-.125	.027	-.073	.202	.110	-.229	.074	-.280
TOK 2	.073	.063	.169	.269	.289*	.372**	-.092	-.079
TOK 3	.368**	.136	.288*	.003	.210	-.123	-.324*	.050
TOK 4	-.124	.182	.061	.131	-.054	-.142	-.214	-.027
TOK 5	.139	.168	.115	.163	.092	-.183	-.267	-.050
TOK 6	-.015	.006	.193	.137	.167	.289*	-.157	-.075
TOK 7	.084	.095	.245	.202	.145	.281*	-.187	.103
TOK 8	-.041	.146	.149	.097	-.021	-.267	.065	-.228

Table 23 Continued

Pearson's Product-Moment Correlation Coefficient I TOK Tenets and Demographics (*N* = 53, N^a = 48)

	Demographics							
TOK Tenets	Science Course	Total Years Exp.	IB Years Exp.	Highest Earned Degree	Under-graduate Major	Grad. Major	Total School Pop.	IB Enroll %[a]
TOK 9	.073	.222	.374**	.097	.113	-.229	-.151	.145
TOK 10	-.089	.129	.140	.174	.140	-.202	-.033	-.067
TOK 11	.009	.356**	.342**	-.033	.066	-.132	-.087	.248
TOK 12	.066	.105	-.022	.016	.047	-.138	-.008	-.078
TOK 13	-.221	.140	.026	.140	.002	-.153	-.104	-.052
TOK 14	-.105	.245	.117	.069	-.025	-.202	-.165	.165
TOK 15	-.240	.311*	.142	-.053	.085	-.027	-.174	-.002

*$p < .05$, ** $p < .01$

Table 24

Summary of Linear Regression Data with TOK Tenets as the Dependent Variable and Demographic Information as the Independent Variables (*N* = 53)

Dependent Variable TOK Tenet	*Independent Variable* Demographics	R^2	*B*	*SE B*	*Beta*	*p*
	Years Total Teaching Experience					
Scientific study is subject to intense critical scrutiny.		.127	.037	.014	.356	.009
Scientific study may have environmental implications.		.100	.029	.014	.302	.041
	Years IB Teaching Experience					
Science is empirical in nature.		.083	.068	.032	.288	.037
Scientific explanations require an understanding of data limitations.		.148	.072	.030	.337	.020

Correlations Between IA Activities and TOK Tenets

Pearson's product-moment correlation analysis was used to determine correlations between the IA activities and the TOK tenets (Table 25). Correlation between IA activities and TOK tenets included those between TOK tenet- "there is not one scientific method" with IA's-graphical analysis and graph development (.350, .337). Graph analysis also had shown significance with TOK tenets-science may involve correlations between a factor and an outcome (.361) and scientific study requires knowledge of and consistent use of technology (.336). IA-spreadsheet analysis on computer showed also showed significance with TOK tenet 12, which is scientific study requires knowledge of and consistent use of technology (.369). IA-simulations showed a significant correlation with TOK tenet-science relies on data from observation (.327). This was also when IA-graphical analysis is correlated with TOK tenets-science involves creativity (.273), causal mechanisms can be tested experimentally (.331), scientific explanations require an understanding of data limitations (.289), and science requires freedom of thought and open-mindedness (.301), and in the correlations between IA-graph development and the TOK tenets-science relies on data from observation (.274), science may involve correlations between a factor and an outcome (.330), causal mechanisms can be tested experimentally (.329), and scientific explanations require an understanding of data limitations (.280). IA-simulations had significant correlation with TOK 7, science may involve correlations between a factor and an outcome (.305). IA-hands-on activities with TOK 2 (.286) and TOK tenet-scientific reasoning can be in the form of a theory requiring a model (.346). Also, in Table 24 TOK tenets 7, 9, 10, 11 and 14 when correlated to IA-participation in field work showed significant correlation (.314, .296, .313, .331, and .276 respectively). IA-spreadsheet analysis on a computer has a significant correlation with TOK 7 (.341) and with TOK 2 (.307). IA-students design experiment correlates significantly with TOK tenet-scientific explanations require an understanding of data limitations (.278) and IA-field trips has a correlation (.302) with TOK tenet-scientific study may have moral and ethical implications (Table 25). Therefore, hypothesis 4 was rejected for the above categories.

Table 25: Pearson's Product-Moment Correlation (r) between IA's and TOK Tenets (n = 53)

IA's	TOK Tenets TOK 1	TOK 2	TOK 3	TOK 4	TOK 5	TOK 6	TOK 7	TOK 8	TOK 9	TOK 10	TOK 11	TOK 12	TOK 13	TOK 14	TOK 15
IA 1	.189	.162	.074	.055	-.039	.024	.058	.017	-.151	-.129	-.046	-.102	.026	-.141	-.076
IA 2	.066	.238	.176	-.113	.084	.027	.035	.010	-.048	.059	-.137	.029	-.015	-.091	-.068
IA 3	.350**	.299	.075	.254	.219	.273*	.361**	.331*	.289*	.301*	.268	.336**	.136	.169	.100
IA 4	.337**	.274*	.077	.243	.193	.229	.330*	.329*	.280*	.262	.252	.246	.140	.182	.110
IA 5	.113	.327**	-.023	.161	.135	.035	.305*	.199	.152	.136	-.029	.230	.096	-.061	.128
IA 6	.064	.286*	.236	.254	.346*	.248	.211	.020	.163	.111	.248	.123	.086	.170	.043
IA 7	.068	-.029	.008	.211	.127	.051	.019	-.049	.050	.023	.118	.248	.022	.041	.093
IA 8	.028	.238	-.008	.161	.049	.128	.314*	.101	.296*	.313*	.331*	.254	.235	.276*	.238
IA 9	.031	.060	.053	.084	.018	-.017	-.044	-.165	-.054	-.032	-.016	-.015	-.030	-.027	-.064
IA 10	-.017	.007	-.168	-.005	-.039	-.039	-.018	.041	-.033	.082	.120	.130	.087	.143	.019
IA 11	-.169	.164	-.099	.065	.096	.096	-.097	.036	-.188	-.065	-.098	.123	.044	-.118	.052
IA 12	.031	.142	.143	.163	.083	.032	.194	.198	.342*	.100	-.122	.144	-.056	.080	.055
IA 13	.152	.307*	.235	.048	.178	-.005	.341*	.143	.255	.115	.156	.369**	-.070	.062	-.119
IA 14	.035	.177	.207	.081	.122	.154	.209	.054	.207	.123	.208	-.003	.139	.236	.073
IA 15	.155	.117	.098	.186	.219	.230	.164	-.045	.174	.191	.186	.251	.039	.024	-.008
IA 16	.222	.170	.051	.067	.054	.121	.226	.146	.278*	.192	.066	.236	-.051	.146	.073
IA 17	.153	.188	.044	.219	.241	.095	.093	.081	.117	.231	.197	.371**	.088	.146	.088
IA 18	-.001	.171	-.016	.009	.100	.108	-.050	-.056	-.028	.247	.021	.234	.302*	.248	.202

**$p < .01$ *$p < .05$

Table 26 describes whether each null hypothesis was rejected or not rejected after examining all relationships. Hypothesis 1 regarding the relationships between options and demographics was not rejected except for demographics, highest earned degree and total school population when it was rejected. Hypothesis 2 regarding significant relationships between IA choices and demographics was not rejected except for demographics, science course taught, years of IB experience, and graduate major when it was rejected. Hypothesis 3 was rejected regarding significant relationships between TOK choices and demographics for science course taught, total years of experience, years of IB experience, undergraduate major, and graduate major.

Lastly, hypothesis 4 was rejected because several significant relationships were found between IA activities and TOK tenets. Graphical analysis correlated with several TOK tenets. The strongest correlations included those with TOK tenets science may involve correlations between a factor and an outcome and there is not one scientific method. The strongest correlations displayed were between the IA activities collaboration with professionals and spreadsheet analysis on a computer with the TOK tenet scientific study requires knowledge of and consistent use of technology.

Summary

Demographic information about the IB science teachers who completed the survey included the course they taught, their years experience, both total and IB, their advanced degrees, the student populations for the schools where they teach and the percentage of IB students enrolled in those schools. Twenty-five teachers in the sample teach biology, 18 teach chemistry, and 10 teach physics.

Table 26: Summary Decisions of the Null Hypotheses

Null Hypothesis	Demographic	Decision
Ho 1: There are no significant relationships between reasons IB science teachers give for option choices and demographics.	Science course	Not Rejected
	Total years experience	Not Rejected
	Years IB experience	Not Rejected
	Highest earned degree	Reject
	Undergraduate major	Not Rejected
	Graduate major	Not Rejected
	Total school population	Reject
	% Enrollment in IB	Not Rejected
Ho 2: There are no significant relationships between the IA choices made by IB science teachers and demographics.	Science course	Reject
	Total years experience	Not Rejected
	Years IB experience	Reject
	Highest earned degree	Not Rejected
	Undergraduate major	Not Rejected
	Graduate major	Reject
	Total school population	Not Rejected
	% Enrollment in IB	Not Rejected
Ho 3: There are no significant relationships between the TOK tenet choices made by IB science teachers and demographics.	Science course	Reject
	Total years experience	Reject
	Years IB experience	Reject
	Highest earned degree	Not Rejected
	Undergraduate major	Reject
	Graduate major	Reject
	Total school population	Not Rejected
	% Enrollment in IB	Not Rejected

Table 26 Continued

Summary Decisions of the Null Hypotheses

Ho 4: There are no significant relationships between IA choices and TOK tenets taught by IB science teachers.	Reject

The most frequently chosen options were biology: evolution and ecology and conservation; chemistry: human biochemistry and environmental chemistry; and physics: optics and astrophysics. Several of the options for each course were not chosen by teachers. The most frequent reasons given for option choices belonged to the category ease, interest, knowledge, and background. Reasons were consistent for the two years they were given. Pearson's correlation data and linear regressions statistics found significant relationships between student preparation for the future with total student population and undergraduate major; and curriculum correlations and relevance with highest earned degree.

Descriptive statistics showed that several of the activities were used more often than others on the average (e.g., hands-on activities, worksheets, and record and present data). Pearson's correlations and linear regression for the significant relationships between demographics and IA activities were for science course taught with the IA's data logging, graph development, literature research, participation in field work, student written investigations and spreadsheet analysis on computer; demographic total years teaching experience with IA collaboration with professionals; demographic graduate major with IA record or present data; and demographic grade levels for the IB school with IA database analysis.

Teacher-designed activities were the most frequent resource identified by respondents. A few correlations were significant for resources used compared to demographics, including science course taught with published lab text and commercial kits and the demographic years of IB experience with published textbooks. Regression analysis did not produce any significant results.

Significant correlations between categories from the two publication years were 2001 categories Planning B, Data Collection, and Data Processing and Presentation with 2007 category Data Collection and Processing and Conclusion and Evaluation. Conclusion and Evaluation also correlated with Data Collection and Processing. No significant results were found from linear regression analysis.

Regarding TOK choices, the TOK tenet “science relies on data from observation” was said to be used often by almost fifty percent (49.1%) of the teachers. Correlation data revealed the TOK tenet “science is empirical in nature” was correlated with the most demographics including science course taught, IB teaching experience, total teaching experience, and undergraduate major. Linear regression analysis revealed relationships between IB teaching experience and the TOK tenets science is empirical in nature and scientific explanations require an understanding of data limitations. Total years teaching experience was significantly correlated to the TOK tenets “scientific study is subject to intense critical scrutiny”, and “scientific study may have environmental implications.”

The chapter concluded with the presentation of Pearson’s correlation data between IA activities and TOK tenets. Several significant correlations were found: IA activity graphical analysis correlated with several TOK tenets, including “science is empirical in nature”, “science involves creativity”, “science may involve correlation between a factor and an outcome”, “causal mechanisms can be tested experimentally”, “scientific explanations require an understanding of data limitations”, “science requires freedom of thought”, and “scientific knowledge of and consistent use of technology.” Graph development correlated with all except science requires freedom of thought, and scientific study requires knowledge of and consistent use of technology; it also correlated to science relies on data from observation. TOK tenet “scientific study requires knowledge of and consistent use of technology” not only correlated with graphical analysis but also with spreadsheet analysis on a computer and collaboration with professionals. The IA activity participation in field work correlated with “scientific explanations require an understanding of data limitations”, “science requires freedom of thought”, and “science is subject to intense critical scrutiny.”

CHAPTER V

SUMMARY, CONCLUSIONS, DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS

Introduction

This chapter begins with an introduction, a summary of the study, conclusions and a discussion comparing these conclusions to previous research. The chapter concludes with implications and recommendations for further research.

Summary of the Study

When examining contemporary literature in education in general and science education specifically, it is often reported there is a need for increased rigor. This became especially true after the congressional legislation of the NCLB Act (2002), where one of its stated purposes was to enhance the benefits to students from rigorous curriculum such as AP and IB. Gollub et al. (2002) recognized the need for "improved research-based understanding of teaching and learning" (p. 1) in these rigorous curriculum.

The mission statement of IB states its aim is to "develop inquiring, knowledgeable and caring young people" by supporting the development of "challenging programs of international education and rigorous assessment" (IB, 2005-2007, Mission, p. 1). IB science-Group 4 comprises one area of a curricular hexagon of six core subjects. Science courses offered in this area include biology, chemistry, physics, and formerly environmental science. Curriculum within each group includes: major topics of study; options which explore these topics more in depth; and IA's, the practical work associated with each curricular area. TOK objectives are also part of each curricular area, but most of these objectives are not assessed. Students are expected to complete a culminating examination which assesses their knowledge of the curriculum area.

The benefit to students from these rigorous curriculums has been previously studied (Clemmitt, 2006; Klopfenstein & Thomas, 2005; Pfeiffenberger et al., 1991; Poelzer & Feldhusen, 1996; Sadler & Tai, 2007). Furthermore, a teacher's impact on student learning in these programs has been examined (Brophy, 1979; Burton et al., 2002; Haycock, 1998; Kyberg, 2007; Wenglinsky, 2002; Wright et al., 1997). This study was designed to investigate specifically the choices teachers make in the IB science curriculum.

This study had three major foci. The first major focus was on the choices IB science teachers make for options, IA activities, IA resources, IA categories and TOK tenets. The second focus examined the relationships between teachers' demographics and these choices. The final focus was the relationships between teachers' choices for IA activities and their TOK tenet choices.

The TOK component of the survey was determined as the TOK tenets correlated with NOS. These tenets were identified with assistance from a panel of experienced science educator who had been identified as experts in NOS. Only those tents which agreed with NOS were included in the survey.

Data for this study were collected by the use of a survey devised and piloted specifically for this study. Several components of the study came from the Weiss et al. study (2001). Fifty-three teachers who responded to the survey had attended either a Level 3 IB conference in Reston, Virginia in April, 2007 or a round-table discussion meeting in Kansas City, Missouri in January, 2008. Participants from the Reston, Virginia conference were initially contacted electronically by IBNA after IRB approval. This contact contained a letter introducing the study and asking for their participation. After agreeing to participate surveys were e-mailed directly to the teachers who volunteered to participate. Participants from the Kansas City, Missouri round-table discussion were either given a survey on the day of the discussion or received an e-mail.

All teachers in the sample were IB science teachers. This sample of teachers included 25 biology teachers, 18 chemistry teachers, and 10 physics teachers.

The first three null hypotheses dealt with comparing the reasons IB science teachers gave for the options they chose to teach, the choices teachers made for IA's, and the amount of time teachers spent on TOK tenets with their demographics. The fourth hypothesis dealt with the relationships between the IA activities teachers chose and the time spent on the various TOK tenets.

Descriptive statistics were calculated for demographics: science course taught, total number of years teaching, number of years IB teaching experience, undergraduate major, highest earned degree, graduate major, total school population, and percent of students enrolled in IB. Pearson's product-moment correlations and linear regression values were determined for tests of statistical significance of the four null hypotheses.

Conclusions

When examining option choices made by IB science teachers it was found that chemistry teachers displayed more variety in their choices than did either biology or physics teachers. Two option choices were chosen by over 50% of the chemistry teachers: Environmental Chemistry and Human Biochemistry. There was a greater variety of other chemistry options chosen. In contrast, biology teachers primarily chose three options: Evolution; Ecology and Conservation; and Neurobiology and Behavior. Few other options were chosen. Nine of the ten physics teachers chose the option Mechanics Extension in the 2007-2008 school year and 6 out of 10 chose the Optics option. Other than Astrophysics, which was chosen by 50% of physics teachers in 2007-2008, the selection of other options was limited.

The primary concern among these IB teachers seemed to be student success or instructional ease while the student was present in their course and not as much on their future success. The IB mission to "develop inquiring, knowledgeable and caring young people who help create a better world through education," (International Baccalaureate, 2005-2007, Mission, p. 1) does not seem to be supported by teachers of this study when the primary reasons for making particular option choices were in the category, interest, background and resource availability, and not the category, student preparation for the future.

There was great variety related to the IA activities teachers used in instruction. The predominant activities used were hands-on activities and worksheets. Several individual teachers reported that they used these IA activities at least 100 times during the year. Only two of the activities were used very little on the average: collaboration with professionals and field trips.

Inquiry is not a great emphasis among IB science teachers. The only components of inquiry being utilized were found in the IA categories Planning A, Planning B, and Design. The primary levels of uses for these categories were "rarely" or "sometimes." There is some emphasis among IB science teachers on data collection and processing, which are important aspects of inquiry listed in NSTA's inquiry position statement (NSTA, 2004).

IB science teachers seem to develop their own activities for IA's or use those developed by other teachers. Published laboratory texts and textbooks were not prominent resources among IB science teachers.

Total number of years teaching experience was shown to have a significant affect on the inclusion of two TOK tenets: scientific study is subject to intense critical scrutiny and scientific study may have environmental implications in instruction for IB science teachers. Significant values were also found when years of IB teaching experience and two different TOK tenets: science is empirical in nature and scientific explanations require an understanding of data limitations relationships were evaluated.

Discussion

When teachers cited reasons related to experience and background like "I was successful with this last year," was supported by Aikenhead (1984) who purported that teachers may draw upon instructional resources such as last year's lesson plans and their own experiences to make "holistic" decisions which integrated science with practical knowledge. Similarly, Henry (1994) noted that informal student outcomes, teacher enjoyment, and teacher compatibility were some of the most prevalent reasons teachers utilize for making curricular choices. This supports Doyle and Ponder (1977-78) who determined that teachers' base their decision making on practicality which is affected by three criteria: instrumentality, congruence, and cost.

Some of the reasons IB science teachers gave for teaching particular options included being "relevant to society," having "international applicability," and "promotes environmental stewardship." This supports Jones and Carter (2007) who suggested that teachers made some of their curricular choices to help students learn how to live in a democratic society.

Evolution was chosen by 100% of the biology teachers in the 2007-2008 school year. In this way IB biology teachers showed they agree with scientists and science educators that evolution is an important topic to be included in a biology curriculum. This was also reflected in the reasons given for this option choice, such as, "It is a major theme in biology and needs to be covered in depth"; "Evolution is a hot topic in KS and I want to make sure the students have a strong background in the material"; and "It is an important theme in biology which ties together all the other topics."

In contrast, the reasons given for the category, preparing students for future studies or assessment was given least often. This seems to disagree with the Lunetta et al. (2007) statement that decisions in teaching "should be driven by the learning outcomes sought for students" (p. 401) and Weiss and Pasley (2004) who identified high quality classrooms as "rigorous" when they challenged students to "engage deeply in the content" (p. 25).

Hands-on activities was the most frequently used IA activity supported Van den Berg et al. (1994), who proposed that when teaching circuits to high school students, hands-on activities were effective for modeling what was involved in circuits. They also found hands-on activities alone were ineffective in teaching all of the scientific relationships required for a complete understanding of circuits. Liu (2006) found that when gas laws were being taught, hands-on activities were effective if they were paired with computer simulations. It is important to note this study found that simulations had one of the lowest usage means for IA activities.

Lunetta (1998) proposed that the number of hands-on activities should not the predominant factor affecting science learning. He considered it is better for students to do a few "authentic" activities than to do many which are superficial. He saw it as important to encourage students in minds-on as well as hands-on (Lunetta 2004), but understood that this is limited by factors such as cost and safety on the high school level (Lunetta et al., 2007). Since hands-on activities were identified as being used numerous times, the question arises as to what level they were incorporated, authentic or superficial.

Worksheets were the second-most used activity for IA's. This could be interpreted to mean IB science teachers understand and utilize the ideas given in the National Research Council's book *America's Lab Report* (2006) where it was noted that when the goal for instruction was student mastery of subject matter, other forms of science instruction could be just as effective as laboratory activities. Weiss and Pasley (2004) in their *Inside the Classroom* proposed that the "quality of lessons did not depend on whether the teacher used a 'reform-oriented' approach or a traditional approach. Some lessons judged to be effective were traditional in nature, using lectures and worksheets" (p. 24). Classrooms were deemed high quality in this study when they were both "respectful and rigorous" and challenged students to "engage deeply with the content" (p. 25).

Since worksheets were identified as one of the most prominent IA activities seems to indicate IB teachers are abandoning true laboratory experiences (Hawkes, 2004). Activities like students' design experiments and participation in field work were considerably lower in frequency than worksheets. This can also be seen in the area of IA categories. Although data collection and data processing were some of the most frequently used categories for IA's, the design category was significantly lower. It is not known how students are directed to collect data, but as a result of the design aspects of inquiry not being predominant it may be after teacher directions are given or "cookbook" laboratory activities are followed. This does not allow students "to identify and ask appropriate questions that can be answered through scientific investigations" (NSTA, 2004, p. 2) or become involved in laboratory processes and developing safe and conscientious laboratory practices (NSTA, 2007).

Hofstein and Lunetta (2003) cautioned that although it is important to use laboratory activities in instruction, inquiry alone is not sufficient to assure students gain a complete understanding of science. Coulter (1966) found that inductive laboratory approaches were not only just as effective as a deductive approach for student instruction and success, but they also were better suited to teaching cause and effect relationships and making judgments after examining evidence, two important skills for science literacy. Gardiner and Farregher (1997) found that even when the laboratory activities performed by students were qualitative and confirmatory and less than those required by the course outline, students still were able to answer laboratory-based questions on exams. More specifically studies have been done relating student success on standardized examinations to hands-on and inquiry activities (Brown & Moore, 1996; Chang & Mao, 1998; Kaiser, 1996; Stohr-Hunt, 1996).

In this study the activity, record or present data had a level of frequency below hands-on activities and worksheets, showing a trend similar to the one found by Weiss et al. (2001). They found in their report on the *2000 National Survey of Science and Mathematics Education* that answering textbook and worksheet questions comprised 72% of the instructional activities students complete during a week while hands-on/laboratory activities comprised 71% of their activities. They also found that the activity, record or present data comprised 54% of students' activities. The IB teachers mirrored Weiss et al. in that some of the most infrequent activities found in the Weiss et al. study were design or implement their own investigations, participate in field work, and take field trips.

IB does not dictate what activities a teacher chooses for IA's; however, they direct that teachers include at least one activity for each topic or option and at least two activities for each IA category (Design; Data Collection and Processing; and Conclusion and Evaluation). Yet there is much discussion among IB science teachers on the IBO website's discussion board that IA scores are consistently moderated to be lower than teachers' original scores. Part of this may be a result of the prevalent use of worksheets as IA activities.

This study found the published laboratory textbooks were of limited use by IB science teachers. In contrast, Tamir and Lunetta (1981) noted that laboratory handbooks were one of the major resources used by teachers for laboratory activities.

The TOK tenets included in this study were determined to be in agreement with NOS. Factors that affect the level of use of NOS are prevalent (Abd-El-Khalick et al., 1998; Brickhouse & Bodner, 1992; Duschl & Wright, 1989; Hobson, 1993; Lederman, 1995). These studies found the reasons teachers identified for not including NOS were the pressure to cover content, classroom management and organizational issues, concern for student abilities, institutional constraints, admitted lack of NOS understanding or a lack of resources.

Emphasis on TOK components is being encouraged by IBO for all content areas and in the new curriculum cycle for Group 4. This is evident by the amount of time spent discussing TOK issues at the Reston, Virginia workshop which most of the participants of this study attended. Zemplen (2007) saw this as a positive aspect of IB. Although teachers are encouraged to include TOK tenets in their instruction, few TOK tenets are directly assessed in student examinations when completing an IB course. This may be one factor which caused the level of use which was predominant for TOK tenets to be "sometimes" in this study.

This may also be related to the impact of teachers' ideas and beliefs about TOK. Numerous studies have been conducted examining NOS and how teachers' understanding and beliefs about NOS does or does not affect their classroom practices or behavior (Brickhouse, 1989, 1990; Duschl & Wright, 1989; Lederman, 1999; Lederman & Zeidler, 1987). Previous research reported that teachers' understanding of NOS affects their students' conceptions (Lederman, 2007). The results of this study indicate that professional development opportunities are needed to help IB teachers develop understanding of TOK tenets and to promote their use. Unless teachers view NOS as an important curricular component they will tend to not include it in their instruction. If IB considers TOK as important, and evidence from the quantity of time spent on TOK at both conferences indicates they do, more needs to be done to support use of TOK tenets in classroom instruction such as requiring teachers to document instruction on TOK tenets like is done with technology use in IA's.

Only low correlations were found between IA activities and TOK tenets. Research is limited on the relationships between NOS ideas and laboratory practices except where discussions of inquiry are concerned. Lazarowitz and Tamir (2004) saw laboratory experiences as providing students with opportunities to confront misconceptions, manipulate data, develop skills in logical thinking, and to build values as they relate to the nature of science. Lederman (2007) commented that often NOS was confused with science processes or science inquiry. One way he distinguished the two was to point out that inquiry was more related to collecting and analyzing data while understanding NOS requires students: to be able to differentiate between observation and inference and between scientific laws and theories; to understand that scientific knowledge is imaginative, creative and theory-laden; and to know that science is practiced within a culture which is never absolute or certain (Lederman, 2007). The only IA activity associated with data collection to show significant correlation with a TOK tenet was data logging with science relies on data from observation. This correlation does not offer much support for the ideas of Lazarowitz and Tamir (2004) or Lederman (2007).

Implications

It was shown in this study that teachers seemed to base their decisions for curricular choices more on their students' or their own personal interest and background rather than on preparing students for the future. There may be various reasons for this including lack of time to prepare to teach unfamiliar curriculum, teachers' lack of background, lack of support for teaching the other curriculum, or lack of resource availability. Regardless, in order for teachers' reasons to be more in line with the IBO mission statement which identifies preparing students for impacting the future, it seems necessary to investigate this matter further.

Use of IBO's OCC was limited by teachers in this study. Teachers are encouraged to use this resource whenever they attend conferences or workshops associated with IBO. It would appear that the OCC is not fulfilling the needs of the teacher. This may be due to the site not being user friendly, teachers not having the time to fully investigate the site, or teachers not being comfortable with this form of technology. No matter the reason, the OCC does not appear to be filling the needs of the IB science teacher.

Inquiry is not a major emphasis among the IB science teachers participating in this study although IBO deems it as important by requiring inquiry-like laboratory designs and promoting inquiry in their mission statement. One reason for this may be that IB science teachers do not have the pedagogical content knowledge necessary to be comfortable with choosing to include more inquiry in their curriculum and instruction. Currently this is dealt with as IBO modifies students' scores on IA's and encourages increased inquiry. This is not enough. If teachers are uncomfortable and unprepared to incorporate inquiry into their curriculum and instruction, then credentials for IB teachers may need to include that teachers have the ability, desire, or support to use inquiry, and/or education regarding what inquiry is and how to use it can be provided in carefully planned professional development.

TOK tenets were only used sometimes by IB science teachers participating in this study. TOK is deemed important by IBO. This infrequent use implies that IB science teachers either do not view TOK as important or they do not think they have the time to deal with TOK concepts in their curriculum and instruction while preparing students for their exams. Steps need to be taken to promote TOK use among IB science teachers. This might be done by including more TOK on IB exams and/or providing teachers with materials and pedagogy which connect the core curriculum more concretely with TOK.

Recommendations for Future Studies

The main purpose of this study was to examine the choices IB science teachers make for curriculum and instruction. The 2006-2007 and 2007-2008 school years provided the data about these choices. During this time a major curriculum change occurred. It is interesting to note that the options chosen most often by physics teachers in this study, Mechanics Extension and Optics, will no longer be option choices after 2008. A future ethnographic study could delve into how teachers dealt with their favorite options no longer being available if these option objectives were not contained within the core curriculum.

This study needs to be replicated on what choices teachers make after the new IB curriculum guide is the only curriculum influencing teachers' choices. This could help inform IBO about the needs for IB teachers' professional development. It would help to focus on areas where teachers make limited choices even though they are deemed important enough to include in the curriculum guides by IBO. These professional development opportunities could help to promote teachers' use of more options, a greater variety of IA activities, more inquiry type activities for IA, more inquiry-like categories of Design, Data Collection and Processing, and Conclusion and Evaluation, and greater TOK utilization in their classrooms. This could help teachers expand beyond the use of worksheets in their instruction. Further studies could then be done to investigate what impact professional development has on these choices.

The second recommendation would be to perform a series of case studies where selected teachers would be interviewed to determine why they made their choices. This qualitative study could also investigate teachers' interpretations regarding the IA activities for this study. It is unknown what teachers actually meant when they reported that they used 100 hands-on activities or worksheets for IA activities. It would be interesting to investigate the quality of instruction done by IB science teachers directly because quality instruction can include worksheets (Weiss & Pasley, 2004). Are IB science teachers using both hands-on activities and worksheets to connect students to content at a rigorous level?

Since the OCC was not used extensively by teachers in this study, it appears necessary to do a needs study among IB science teachers to determine what resources, topics, and other information do they need or would use. Data from this study could then be used to assist web site planners who could then promote changes on the web site which have been made in response to teachers' needs. Professional development could also be done which focuses specifically on the use of the OCC.

Instruction including TOK tenets was limited by teachers in this study. Since NOS and thus TOK are important to students' science literacy IBO should identify why teachers are not teaching TOK tenets in their science classrooms and provide materials and professional development for its increased use. One of the issues may be that teachers do not feel the push to include TOK tenets because of time issues and the fact that most TOK tenets do not have explicit questions asked about them on the exam indicating they are less important. If science literacy is important to IBO, then inclusion of more TOK tenets on the external IB exam should be considered.

The last recommendation would be to examine the effect IB science teachers' choices have on student learning in IB science classes and success on their IB examinations. This would relate teaching practice to student success and could provide support for identifying master IB teachers who could be leaders in professional development for IB. A mixed design would be the most effective method to address this recommendation.

Summary

This chapter included an introduction and a summary of the study. Conclusions based upon the findings from the study were given and discussed as they related to the literature in the areas investigated in the study. This discussion was followed by implications and several recommendations for further research.

APPENDIX A

LETTERS SENT TO PARTICIPANTS

Letter to potential participants sent by IBNA electronically.

September 15, 2007

Dear Reston Level 3 Group 4 Training Participant:

I am writing this letter to ask for your assistance. Currently I am working on my doctorate in science education. As part of this program I am conducting a research study on the choices International Baccalaureate (IB) teachers make for options and internal assessment (laboratory program), and how they incorporate Theory of Knowledge into their teaching.

This study will be based upon a survey of IB Group 4 teachers. You have been selected as one of the people to participate in this survey because you are an experienced IB teacher who attended the level 3 training in Reston, VA in April of 2007. By your presence at the training you have shown you have bought into the same characteristics we expect from our students in the learner profile. This includes being knowledgeable, being inquirers, and being reflective. These are the characteristics which are necessary to answer the questions in my study and provide feedback in an area where limited research has been done.

This study will benefit you and all IB group 4 teachers by helping to identify areas where professional development may be needed. By examining the different choices teachers make, this study can provide for future collaboration among IB teachers and influence the curricular choices made in the next implementation cycle. Since TOK components have been included as an emphasis for each IB group, this study will give some indication of the level of impact TOK has and provide information on the components teachers use in Group 4.

When you agree to participate, you will be asked to fill out a survey which has been designed to be brief and to the point. Each survey will be coded for the purpose of processing. Your responses will be held in strict confidence. All published results will be summarized and data for individual responses will not be released.

To participate in this survey, please, reply to this email to ljauss@nkcsd.k12.mo.us prior to December 1, 2007. Include in your reply your name, address and phone number if desiring a hard copy of the survey. If you would prefer that I send the survey via electronic mail (e-mail), please reply with your name, e-mail address, and phone number. I will send your survey in November.

I hope that you will choose to take part in this study since your participation is essential to study the IB program. If you are interested in the results of my study, please indicate that wish in your reply.

Sincerely,

Lanett S. Jauss Ed. Spec.

Lloyd H. Barrow –Dissertation Director
Professor Science Education

Form sent with letter to potential participants by IBNA electronically

What Choices do North American IB Group 4Teachers Make in Curriculum and Instruction?
Study Conducted by Lanett S. Jauss
Participant Information Form

Name: ____

Preferred Method to Receive Survey: Paper copy mailed ________ Email ________

Preferred Address (Street, City, State, Zip code): ____

____

Email Address: ____

Phone number: ____

IB Subjects taught: Biology __________ Chemistry ________ Physics _

IB Course Level taught: SL __________ HL __________ Both ________

Wish to receive results of the survey: Yes _________ No __________

Letter sent to sample who agreed to participate in this doctoral study after IRB approval.

Lanett S. Jauss
109 E. 12th St.
Higginsville, MO 64037

December 12, 2007

Dear NAME OF PARTICIPANT:

Thank you again for agreeing to participate in my doctoral study. You will find a survey for the curricular area you teach attached to this email. Please fill out the survey and return it to me by January 7, 2008. Because I am a teacher like yourself, I know how valuable your time is, especially now that the end of the semester is drawing near. Hopefully you will be able to find a few minutes to fill out the survey to give me your input on some important issues dealing with what choices you make as a science teacher in the IB program. Your input is valuable to me, to IB, and to others who may use this research in the future.

If you have trouble accessing the survey or need more time, please let me know. I want to make this as easy for you as possible. If you prefer to mail the survey to me, my address is given above. Remember, if you have any questions about this study, please feel free to contact Lanett Jauss at 660-422-1298; email: ljauss@nkcsd.k12.mo.us or Dr. Lloyd Barrow at 573-882-7457. For additional information regarding participation in doctoral research, you may contact the University of Missouri Internal Review Board (which oversees human subjects) at 573-882-9585.

Sincerely,

Lanett S. Jauss, Ed. Spec.
IB Group 4 Teacher-North Kansas City High School
University of Missouri Doctoral Student

Dr. Lloyd H. Barrow
Professor Science Education
Dissertation Director

Letter to potential participants attending a roundtable discussion in Kansas City, Missouri January 25, 2008

January 17, 2008

Dear IB Group 4 Teacher:

As an experienced IB teacher participating in this roundtable meeting, you are showing you have the same characteristics we expect from our students in the learner profile. This includes being knowledgeable, being inquirers, and being reflective. These are the characteristics which are necessary to answer questions and to provide feedback in an area where limited research has been done specifically in the IB curriculum and instruction areas. Thus you are being requested to participate in my doctoral study which involves filling in a short survey on the choices International Baccalaureate (IB) teachers make for options and internal assessment, and to what extent they incorporate theory of knowledge (TOK) into their teaching. Anthony Tait, Head of School Service & Professional Development for IBNA and Michael Dean, Research Manager for IBNA have reviewed this study and given their approval and their permission to contact you.

This study will benefit you and all IB group 4 teachers by helping to identify areas where professional development may be needed. By examining the different choices teachers make, this study can provide for future collaboration among IB teachers and help influence the curricular choices made in the next implementation cycle. Since TOK components have been included as an emphasis for each IB group, this study will give some indication of the level of impact TOK has in group 4 classrooms and provide information on the TOK components group 4 teachers use most.

For your convenience I have included a copy of the survey along with this letter. You will only need to fill in one of the first three pages of the survey. Those pages are specific to the content area you teach. Then, please finish the survey by completing the final 3 pages which apply to all content areas.

If you have any questions about this study, please feel free to contact Lanett Jauss at 660-422-1298 (cell); 660-584-6677 (home) or Dr. Lloyd Barrow at 573-882-7457. For additional information regarding participation in doctoral research, you may contact the University of Missouri Internal Review Board (which oversees human subjects) at 573-882-9585. Should you have any questions for the IB North America office, please contact the Research Manager, Michael Dean at ichael.dean@ibo.org.

I hope that you will choose to take part since your participation is essential to this study of the IB program. You may get an electronic copy of the survey by emailing me at ljauss@nkcsd.k12.mo.us , send this copy by snail mail at the address listed above, or FAX this copy to 816-413-5935. Please return your survey by February 15, 2008.

Sincerely,

Lanett S. Jauss, Ed. Spec.
IB Group 4 Teacher-North Kansas City High School
University of Missouri Doctoral Student

Dr. Lloyd H. Barrow
Professor Science Education
Dissertation Director

If you wish to receive the results of this study please fill in the following information:

Name:____

Contact Information: (email or FAX): ____

Reminder letter sent to those participants who had not returned their completed survey after agreeing to participate in the study.

February 15, 2008

Dear: NAME OF PARTICIPANT

This note is to remind you that I have not received your IB survey. Your ideas and information are extremely important. They will provide vital information as we examine curriculum and instruction among IB group 4 teachers.
I am resending the survey for your curricular area. If you would rather FAX the completed survey to me my FAX number is 816-413-5935. If you have trouble accessing the survey, please let me know. I want to make this as easy for you as possible. If you prefer to mail the survey to me, my address is given above.
Remember, if you have any questions about this study, please feel free to contact Lanett Jauss at 660-422-1298; email: ljauss@nkcsd.k12.mo.us or Dr. Lloyd Barrow at 573-882-7457. For additional information regarding participation in doctoral research, you may contact the University of Missouri Internal Review Board (which oversees human subjects) at 573-882-9585. Should you have any questions for the IB North America office, please contact the Research Manager, Michael Dean at michael.dean@ibo.org who supports this study.

Sincerely,

Lanett S. Jauss, Ed. Spec.
IB Group 4 Teacher-North Kansas City High School
University of Missouri Doctoral Student

Dr. Lloyd H. Barrow
Professor Science Education
Dissertation Director

APPENDIX B

SURVEYS SENT TO PARTICIPANTS

IB BIOLOGY SURVEY

I. IB Curriculum

Directions: Place an X next to all of the responses that represent your choices as an IB biology teacher.

A. Option choices for the 2007-2008 school year:

I do not currently teach IB Group 4 classes _______

2007 Options Standard Level (SL)

Option A: Human nutrition and health _______
Option B: Physiology of exercise _______
Option C: Cells and energy _______

Options SL and HL

Option D: Evolution _______
Option E: Neurobiology and behavior _______
Option F: Microbes and biotechnology _______
Option G: Ecology and conservation _______

Options HL

Option H: Further human physiology _______

2001 Options SL

Option A Diet and human nutrition _______
Option B Physiology of exercise _______
Option C Cells and energy _______

Options Standard Level/Higher Level (SL/HL)

Option D Evolution _______
Option E Neurobiology and behavior _______
Option F Applied plant and animal science _______
Option G Ecology and conservation _______

Options Higher Level (HL)

Option H Further human physiology _______

B. Option choices used in 2006-2007 school year:

I did not teach group 4 IB classes in 2006-2007 _______

2001 Options SL

Option A Diet and human nutrition _______

Option B Physiology of exercise _______
Option C Cells and energy _______

Options Standard Level/Higher Level (SL/HL)

Option D Evolution _______
Option E Neurobiology and behaviour _______
Option F Applied plant and animal science _______
Option G Ecology and conservation _______

Options Higher Level (HL)

Option H Further human physiology _______

C. Reasons for option choices: On the lines below, please answer this question: Why did you choose each option you chose to teach in the 2007-2008 school year?

Option choice ________. Reason: ____

Option choice ________. Reason: ____

Why did you choose each option you chose to teach in the 2006-2007 school year?

Option choice ________. Reason: ____

Option choice ________. Reason: ____

5. **Internal Assessment (IA)**

A. Types of Internal Assessment Exercises

Directions: Indicate the number of times you used each of the following types of activities with students during the 2006-2007 school year.

Activity	Number of times performed this activity during 2006-2007 school year.	Did not do this activity during the 2006-2007 school year.
Database analysis		
Data logging		
Graph analysis		
Graph development		
Simulations		
Hands-on activities		
Student written investigations		
Participation in field work		
Worksheets		
Literature research		
Model building		
Group projects		
Spreadsheet analysis on computer		
Record or present data		
Audio/visual presentations		
Students design their own experiment		
Extended investigations in collaboration with professionals		
Field trips		

List other activities not listed above and the frequency of their use

Activities **Number of times used activity in 2006-2007**

________________________________ ____________________
________________________________ ____________________
________________________________ ____________________

5. **Resources-**

Directions: Mark an X below each category that best expresses the frequency of use of resources for activities that are part of your IA curriculum per year.

	Frequencies			
Resource	Never	Rarely (1-6 IA's)	Sometimes (7-12 IA's)	Often (more than 12 IA's)
IBO –OCC				
Published texts				
Published lab texts				
Commercial kits				
Teacher designed				
Workshop/convention				
Other teachers				

List other resources not listed above and the frequency of their use

Resources **Frequency (per year**

________________________________ ____________________
________________________________ ____________________
________________________________ ____________________

5. **Emphasis placed on different Internal Assessment categories**

Directions: Mark an X below the column that best describes the number of activities you use for each IA category during a school year.

	Frequencies			
Category	Minimum (2 IA's only)	Rarely (3-6 IA's)	Sometimes (7-12 IA's)	Often (more than 12 IA's)
Design (2007)				
Planning A (2001) (Problem, hypothesis, & variables)				
Planning B (2001) (Materials and methods)				
Data Collection and Processing (2007)				
Data Collection (2001)				

Data Processing & Presentation (2001)				
Conclusion & Evaluation (2001 & 2007)				

III. Theory of Knowledge (TOK)

Directions: Mark an X below the column that best describes the frequency for using the following TOK tenets for group 4 instruction during the 2006-2007 school year.

Tenets	Never	Rarely (A few times a year)	Sometimes (Once or twice each topic/option)	Often (More than twice for each topic /option)
There is not one scientific method.				
Science relies on data from observation.				
Science is empirical in nature.				
Science includes inductive & deductive reasoning.				
Scientific explanation can be in the form of a theory requiring a model.				
Science involves creativity.				
Science may involve correlations between a factor and an outcome.				
Causal mechanisms can be tested experimentally .				
Scientific explanations require an understanding of data limitations.				
Science requires freedom of thought and open-mindedness.				
Scientific study is subject to intense critical scrutiny.				
Scientific study requires knowledge of and consistent use of technology.				
Scientific study may have moral and ethical implications				
Scientific study may have economic implications.				
Scientific study may have environmental implications.				

IV. Demographics

A. **Teaching Experience**

1. Science teaching experience including current (years):_____________
2. IB science teaching (years):________

B. **Advanced degree Experience**

1. Undergraduate major: ____
2. Highest earned degree: ____
3. Graduate major for highest degree:____

C. Type/Size of School

1. IB Diploma School Yes _________ No __________
2. Grade Levels 9-12 _________ 10-12 ________ 11-12 ________
3. Student Population (Number of students): ______________
4. Percentage of total number of students enrolled in the IB program ______________
5. Type of IB enrollment: Open ________ Selected ___________

D. Comments:____
____
____

Thank you for participating in this doctoral survey. Your information and comments will be valuable when examining the answer to my research question, What Choices Do IB Group 4 Teachers Make in Curriculum and Instruction?

Lanett S. Jauss
University of Missouri Doctoral Student
IB Group 4 Teacher

Lloyd Barrow
Research Advisor
University of Missouri

IB CHEMISTRY SURVEY

5. **IB Curriculum**

Directions:

Place an X next to all of the responses that represent your choices as an IB chemistry teacher.

A. Option choices used for the 2007-2008 school year:

I do not currently teach IB Group 4 classes……………………………………..._______

2007 Options Standard Level (SL) and High Level (HL)

Option A: Modern analytical chemistry ……………………………………….. _______
Option B: Human biochemistry ………………………………………………. _______
Option C: Chemistry in industry and technology ………………………………. _______
Option D: Medicines and drugs ………………………………………………. _______
Option E: Environmental chemistry ………………………………………….. _______
Option F: Food chemistry ……………………………………………………. _______
Option G: Further organic chemistry ………………………………………….. _______

2001 Options SL

Option A: Higher physical organic chemistry……………………………………. _______

Options SL/HL

Option B: Medicines and drugs…………………………………………………... _______
Option C: Human biochemistry…………………………………………………. _______
Option D: Environmental chemistry……………………………………………... _______
Option E: Chemical industries……………………………………………..……. _______
Option F: Fuels and energy ………………………………………………..…… _______

Options HL

Option G: Modern analytical chemistry…………………………………….…. _______
Option H: Further organic chemistry ……………………………………………._______

B. Option choices used in 2006-2007 school year:

I did not teach group 4 IB classes in 2006-2007………………………...……….._______

2001 Options SL

Option A: Higher physical organic chemistry……………………………………. _______

Options SL/HL

Option B: Medicines and drugs…………………………………………………... _______
Option C: Human biochemistry…………………………………………………. _______
Option D: Environmental chemistry……………………………………………... _______
Option E: Chemical industries……………………………………………..……. _______
Option F: Fuels and energy ………………………………………………..…… _______

Options HL

Option G: Modern analytical chemistry…………………………………….…. _______
Option H: Further organic chemistry ……………………………………………._______

C. Reasons for option choices: On the lines below, please answer this question: Why did you choose each option you chose to teach in the 2007-2008 school year?

Option choice ________. Reason: ____

Option choice ________. Reason: ____

Why did you choose each option you chose to teach in the 2006-2007 school year?

Option choice ________. Reason: ____

Option choice ________. Reason: ____

5. **Internal Assessment (IA)**

A. Types of Internal Assessment Exercises

Directions: Indicate the number of times you used each of the following types of activities with students during the 2006-2007 school year.

Activity	Number of times performed this activity during 2006-2007 school year.	Did not do this activity during the 2006-2007 school year.
Database analysis		
Data logging		
Graph analysis		
Graph development		
Simulations		
Hands-on activities		
Student written investigations		
Participation in field work		
Worksheets		
Literature research		
Model building		
Group projects		
Spreadsheet analysis on computer		
Record or present data		
Audio/visual presentations		
Students design their own experiment		
Extended investigations in collaboration with professionals		
Field trips		

List other activities not listed above and the frequency of their use

Activities **Number of times used activity in 2006-2007**

___________________________________ _____________________

___________________________________ _____________________

___________________________________ _____________________

5. **Resources-**

Directions: Mark an X below each category that best expresses the frequency of use of resources for activities that are part of your IA curriculum per year.

	Frequencies			
Resource	Never	Rarely (1-6 IA's)	Sometimes (7-12 IA's)	Often (more than 12 IA's)
IBO –OCC				
Published texts				
Published lab texts				
Commercial kits				
Teacher designed				
Workshop/convention				
Other teachers				

List other resources not listed above and the frequency of their use

Resources **Frequency (per year**

___________________________________ _____________________

___________________________________ _____________________

___________________________________ _____________________

5. **Emphasis placed on different Internal Assessment categories**

Directions: Mark an X below the column that best describes the number of activities you use for each IA category during a school year.

	Frequencies			
Category	Minimum (2 IA's only)	Rarely (3-6 IA's)	Sometimes (7-12 IA's)	Often (more than 12 IA's)
Design (2007)				
Planning A (2001) (Problem, hypothesis, & variables)				
Planning B (2001) (Materials and methods)				
Data Collection and Processing (2007)				
Data Collection (2001)				

Data Processing & Presentation (2001)				
Conclusion & Evaluation (2001 & 2007)				

III. Theory of Knowledge (TOK)

Directions: Mark an X below the column that best describes the frequency for using the following TOK tenets for group 4 instruction during the 2006-2007 school year.

Tenets	Never	Rarely (A few times a year)	Sometimes (Once or twice each topic/option)	Often (More than twice for each topic /option)
There is not one scientific method.				
Science relies on data from observation.				
Science is empirical in nature.				
Science includes inductive & deductive reasoning.				
Scientific explanation can be in the form of a theory requiring a model.				
Science involves creativity.				
Science may involve correlations between a factor and an outcome.				
Causal mechanisms can be tested experimentally .				
Scientific explanations require an understanding of data limitations.				
Science requires freedom of thought and open-mindedness.				
Scientific study is subject to intense critical scrutiny.				
Scientific study requires knowledge of and consistent use of technology.				
Scientific study may have moral and ethical implications				
Scientific study may have economic implications.				
Scientific study may have environmental implications.				

IV. Demographics

A. **Teaching Experience**

1. Science teaching experience including current (years):______________
2. IB science teaching (years):________

B. **Advanced degree Experience**

1. Undergraduate major: ____

2. Highest earned degree: ____

3. Graduate major for highest degree:____

C. Type/Size of School

1. IB Diploma School Yes _________ No __________
2. Grade Levels 9-12 _________ 10-12 ________ 11-12 ________
3. Student Population (Number of students): ______________
4. Percentage of total number of students enrolled in the IB program ______________
5. Type of IB enrollment: Open ________ Selected ___________

B. Comments:____
____
____

Thank you for participating in this doctoral survey. Your information and comments will be valuable when examining the answer to my research question, What Choices Do IB Group 4 Teachers Make in Curriculum and Instruction?

Lanett S. Jauss
University of Missouri Doctoral Student
IB Group 4 Teacher

Lloyd Barrow
Research Advisor
University of Missouri

IB PHYSICS SURVEY

I. IB Curriculum

Directions: Place an X next to all of the responses that represent your choices for options as an IB physics teacher.

A. Option choices used for the 2007-2008 school year:

I do not currently teach IB Group 4 classes………………………………………… _______

2007 Options Standard Level (SL)

Option A: Sight and wave phenomena …………………………………………… _______
Option B: Quantum physics and nuclear physics ………………………………… _______
Option C: Digital technology ………………………………………………….. _______
Option D: Relativity and particle physics ……………………………………... _______

Options Standard Level and High Level

Option E: Astrophysics ……………………………………………………….. _______
Option F: Communications …………………………………………………… _______
Option G: Electromagnetic waves ……………………………………………. _______

Options High Level

Option H: Relativity …………………………………………………………... _______
Option I: Medical physics …………………………………………………….. _______
Option J: Particle physics …………………………………………………….. _______

2001 Options SL

Option A: Mechanics extension ………………………………………………. _______
Option B: Quantum physics and nuclear physics………………………………… _______
Option C: Energy extension…………………………………………………… _______

Options SL/HL

Option D: Biomedical physics………………………………………………… _______
Option E: The history and development of physics…………………………… _______
Option F: Astrophysics………………………………………………………... _______
Option G: Relativity…………………………………………………………... _______

Options HL

Option H: Optics……………………………………………………………....... _______

B. Option choices used in 2006-2007 school year:

I did not teach group 4 IB classes in 2006-2007………………………………….. _______

2001 Options SL

Option A: Mechanics extension ………………………………………………. _______
Option B: Quantum physics and nuclear physics………………………………… _______
Option C: Energy extension…………………………………………………… _______

Options SL/HL

Option D: Biomedical physics………………………………………………… _______
Option E: The history and development of physics…………………………… _______
Option F: Astrophysics………………………………………………………... _______
Option G: Relativity…………………………………………………………... _______

Options HL

Option H: Optics……………………………………………………………....... _______

5. **Reasons for option choices: On the lines below, please answer this question: Why did you choose each option you chose to teach in the 2007-2008 school year?**

Option choice _________. Reason: ____

Option choice _________. Reason: ____

Why did you choose each option you chose to teach in the 2006-2007 school year?

Option choice _________. Reason: ____

Option choice _________. Reason: ____

5. **Internal Assessment (IA)**

A. Types of Internal Assessment Exercises

Directions: Indicate the number of times you used each of the following types of activities with students during the 2006-2007 school year.

Activity	Number of times performed this activity during 2006-2007 school year.	Did not do this activity during the 2006-2007 school year.
Database analysis		
Data logging		
Graph analysis		
Graph development		
Simulations		
Hands-on activities		
Student written investigations		
Participation in field work		
Worksheets		
Literature research		
Model building		
Group projects		
Spreadsheet analysis on computer		
Record or present data		
Audio/visual presentations		
Students design their own experiment		
Extended investigations in collaboration with professionals		
Field trips		

List other activities not listed above and the frequency of their use

Activities **Number of times used activity in 2006-2007**

________________________________ ___________________

________________________________ ___________________

________________________________ ___________________

5. **Resources-**

Directions: Mark an X below each category that best expresses the frequency of use of resources for activities that are part of your IA curriculum per year.

	Frequencies			
Resource	Never	Rarely (1-6 IA's)	Sometimes (7-12 I.A's)	Often (more than 12 IA's)
IBO –OCC				
Published texts				
Published lab texts				
Commercial kits				
Teacher designed				
Workshop/convention				
Other teachers				

List other resources not listed above and the frequency of their use

Resources **Frequency (per year**

________________________________ ___________________

________________________________ ___________________

________________________________ ___________________

5. **Emphasis placed on different Internal Assessment categories**

Directions: Mark an X below the column that best describes the number of activities you use for each IA category during a school year.

	Frequencies			
Category	Minimum (2 IA's only)	Rarely (3-6 I.A's)	Sometimes (7-12 IA's)	Often (more than 12 IA's)
Design (2007)				
Planning A (2001) (Problem, hypothesis, & variables)				
Planning B (2001) (Materials and methods)				
Data Collection and Processing (2007)				
Data Collection (2001)				

Data Processing & Presentation (2001)				
Conclusion & Evaluation (2001 & 2007)				

III. Theory of Knowledge (TOK)
Directions: Mark an X below the column that best describes the frequency for using the following TOK tenets for group 4 instruction during the 2006-2007 school year.

Tenets	Never	Rarely (A few times a year)	Sometimes (Once or twice each topic/option)	Often (More than twice for each topic /option)
There is not one scientific method.				
Science relies on data from observation.				
Science is empirical in nature.				
Science includes inductive & deductive reasoning.				
Scientific explanation can be in the form of a theory requiring a model.				
Science involves creativity.				
Science may involve correlations between a factor and an outcome.				
Causal mechanisms can be tested experimentally .				
Scientific explanations require an understanding of data limitations.				
Science requires freedom of thought and open-mindedness.				
Scientific study is subject to intense critical scrutiny.				
Scientific study requires knowledge of and consistent use of technology.				
Scientific study may have moral and ethical implications				
Scientific study may have economic implications.				
Scientific study may have environmental implications.				

IV. Demographics

A. **Teaching Experience**

1. Science teaching experience including current (years):______________
2. IB science teaching (years):_________

B. **Advanced degree Experience**

1. Undergraduate major: ____
2. Highest earned degree: ____
3. Graduate major for highest degree:____

C. Type/Size of School

1. IB Diploma School Yes __________ No ___________
2. Grade Levels 9-12 _________ 10-12 _________ 11-12 ________
3. Student Population (Number of students): ______________
4. Percentage of total number of students enrolled in the IB program ______________
5. Type of IB enrollment: Open _________ Selected ___________

D. Comments:____
____
____

Thank you for participating in this doctoral survey. Your information and comments will be valuable when examining the answer to my research question, What Choices Do IB Group 4 Teachers Make in Curriculum and Instruction?

Lanett S. Jauss
University of Missouri Doctoral Student
IB Group 4 Teacher

Lloyd Barrow
Research Advisor
University of Missouri

APPENDIX C

EXAMPLES OF REASONS GIVEN FOR OPTION CHOICES BY CATEGORY

Table 27: EXAMPLES OF REASONS FOR OPTION CHOICE BY CATEGORY

CURRICULUM CORRELATIONS AND RELEVANCE

- Critical to the understanding of the subject
- Matches most closely the curriculum I need to teach to meet expectations.
- Connects with our start of the year ecology unit.
- A major theme in biology and needs to be covered.
- International applicability.
- Facilitates the students' study of anatomy and physiology.
- Elaborate on human anatomy taught in SL.
- Live in Midwest and is an important aspect of life here.
- Students take IB psychology which includes some of the same information.
- Relevant to society.
- Takes advantage of previous biological knowledge.
- Logical continuation of organic chemistry.
- Backbone of the Group 4 project.
- Has many practical, everyday applications.
- Relevant to students' daily lives.
- Part of regular physics class.
- Extensive overlap with core and AHL curriculum.

INTEREST, BACKGROUND, RESOURCE AVAILABILITY

- Same for entire district.
- Student interest in learning about the human body.
- Because I like it – Interesting to me.
- Most popular topic among students.
- College course.
- Taught previously and was successful.
- Student interest.
- Good local resources.
- Materials on hand.
- Familiar to students.
- Time is a factor.
- Easy to teach.

STUDENT PREPARATION FOR FUTURE

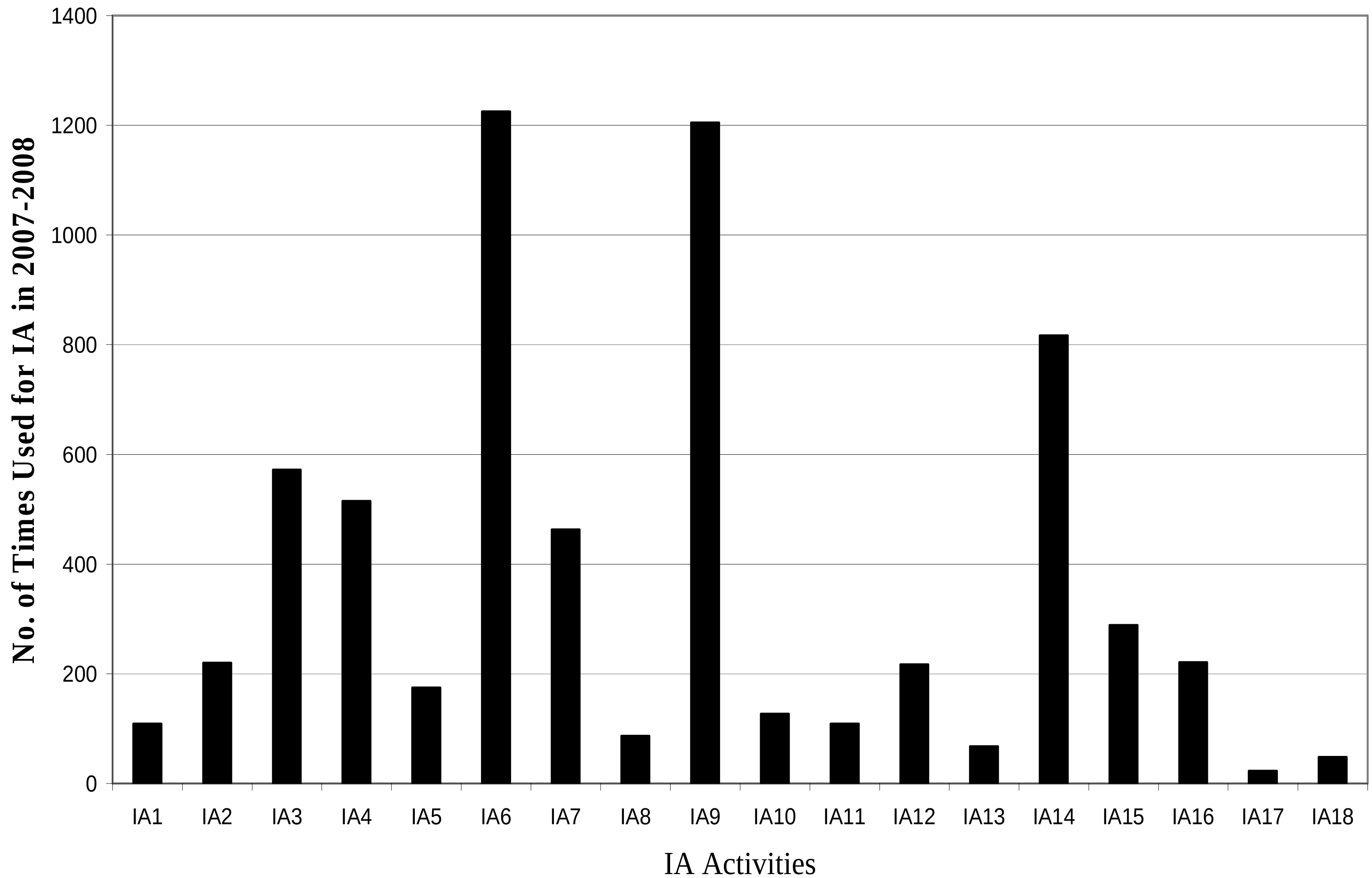
- Majority of students in biology plan on a health field career.
- Students need to be informed about the issues facing the planet.
- Prepare students for provincial exam.
- Prepare students for SAT.
- Many students planning on taking pre-med in college.
- Promotes environmental stewardship.
- Spiral with this option.
- Correlates with AP Physics B test.

APPENDIX D

IA ACTIVITIES GRAPH

Graph 1

IA Activities Used By Sample Teachers for 2007-2008



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