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ANALYSIS OF THE EFFECT OF STUDENT COGNIZANCE OF THE LEARNING CYCLE IN GENERAL CHEMISTRY

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ANALYSIS OF THE EFFECT OF STUDENT COGNIZANCE OF THE LEARNING CYCLE IN GENERAL CHEMISTRY

A DISSERTATION APPROVED FOR THE
DEPARTMENT OF CHEMISTRY AND BIOCHEMISTRY

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The old adage about education smugly states that "Those who can, do; those who cannot, teach." For my part as an educator, I have felt that the only thing I cannot do is give anything less than my best every time I teach. I do not believe that a more honorable profession exists than one that grants the opportunity to inspire others about a subject you love. It is my hope that this project, in some small way, may help future instructors to inspire their own students in the subject they love.

Table of Contents

List of Tables

TABLE

List of Illustrations

GRAPH

Abstract

While the benefits of the using the Learning Cycle have been well researched, one area that has received surprisingly little investigation is the effect that student cognizance of the learning cycle has on student performance in chemistry. The Learning Cycle, with its strong theoretical roots in scientific practice and learning theory, offers a logical opportunity to educate students in the nature of science and metacognition. In addition, by examining the class holistically, students will have the opportunity to better link the lab and lecture components of the course. We hypothesized that since a keen understanding of the nature of science, strong metacognitive ability, and a holistic view of Learning Cycle classes have all been shown to increase student comprehension in general chemistry, students who were taught to understand the Learning Cycle would perform better than students who were not. Statistical analysis of survey and grade data will be presented.

Chapter I

Introduction

Context for the Study

The Learning Cycle is one of the preeminent instructional models for science education. Combining major psychological theories and modeled after the nature of scientific exploration, the Learning Cycle has proven to be an effective model for science education (Marek & Cavallo, 1997). In Learning Cycle style classes, students experience a scientific concept first in laboratory and use observations from the laboratory to "invent" a scientific concept. The Learning Cycle requires that students be active participants in the learning process rather than just passive observers, as they are involved in the creation of knowledge rather than simply receiving instruction on it.

Though it finds widespread usage, questions remain about just how aware students are of the Learning Cycle as a process. Students habitually dismiss laboratory assignments as busy work and fail to see its pedagogical utility, even when the laboratory work directly results in the introduction of new knowledge, as in a Learning Cycle class. Students are rarely, if ever, given an explanation on why they are learning using a certain method, even though such an explanation could cause them to value the laboratory portion more. In addition, without an understanding of the pedagogical rationale behind active learning principles, students often do not properly benefit from this method of instruction (Malikow, 2007; Huxham, 2005; Qualters, 2001). To properly educate students on the usefulness of the Learning Cycle, it is necessary to discuss the theoretical basis for this process with them.

The Learning Cycle was initially created to mimic the method in which new scientific knowledge is uncovered by scientists (Abraham & Renner, 1986). Ironically, though students in Learning Cycle classes are experiencing a microcosm of the mechanism by which science actually operates, the students themselves are not made aware of this fact. As a result, it is unlikely that they are extrapolating the format of the class to anything beyond the class itself. Simply alerting students that they are experiencing science in class could offer significant pedagogical advantages, as students tend to perform better in science classes when they have a better understanding of the nature of science (Songer & Linn, 1991).

In addition, the Learning Cycle has strong connections with psychological learning theory (Bodner, 1986). The cyclical nature of the Learning Cycle mimics the process by which students process new information that was proposed by Jean Piaget (Abraham & Renner, 1986). Instructing students on this aspect of the Learning Cycle could also serve as a way of bolstering their metacognition. Metacognition, simply described as "thinking about thinking", has been linked to increased performance in academic pursuits, not just science classes (Rickey & Stacy, 2000).

General Statement of the Problem

The purpose of this project is to examine what effect cognizance of the Learning Cycle has on student performance in general chemistry. Additional goals are to determine if instructing students on the theoretical basis of the Learning Cycle leads to changes in the students' understanding of the nature of science, their metacognitive processes, or their perception of the connection between laboratory and lecture. Any grade differences between Treatment and Control sections will be explained in the context of these factors.

Significance of the Study

This study will broaden the scope of knowledge surrounding student cognizance of the Learning Cycle. No research currently exists which examines the implications of students who are made aware of the theoretical basis of the Learning Cycle. Possible implications included increased performance in general chemistry, increased student metacognition, and altered perceptions of the nature of science.

If instruction on the theoretical nature of the Learning Cycle is found to have a favorable effect, instruction of the Learning Cycle will prove to be a valuable pedagogical tool for science teachers. Given the widespread usage of the Learning Cycle, as well as ease by which it can be made to fit within an existing curriculum, this technique could find widespread usage by science teachers as a method to increase student performance in science classes.

Research Questions

1. Does instructing students on the theoretical background of Learning Cycle increase student performance in general chemistry? If so, what is this difference most likely a result of?
2. Does instructing students on the theoretical background of the Learning Cycle affect their metacognitive capabilities?
3. Does instructing students on the theoretical background of the Learning Cycle alter their perceptions of the connection between the laboratory and lecture portions of the course?
4. Does instructing students on the theoretical background of the Learning Cycle alter their perceptions of the nature of science?

Chapter II

Current Literature

Cognitive Development

The Swiss developmental psychologist Jean Piaget proposed a theory of intellectual development that became known as "Piaget's theory of cognitive development" (1967). Piaget's theory of cognitive development states that students progress through four stages as they grow and mature, with different thought processes and nuances associated with each. The four stages of Piaget's theory of cognitive development are:

- Sensorimotor
- Preoperational
- Concrete operational
- Formal Operational

Of these four, concrete operational and formal operational students are of the most use to educators in college courses, since students ordinarily achieve concrete operational thinking before beginning college (Ginsburg & Opper, 1979). Though students naturally progress through the first three stages during normal growth and development, many adults live their entire lives having never reached the formal operational stage (Huitt & Hummel, 2003).

Concrete operational students may be ascribed a number of different characteristics. However, perhaps most important is the ability to reason with concrete objects or concepts, or those that they can visualize (Piaget & Inhelder, 1969). For example, they are capable of conserving a number of parameters, such as mass, length, number, weight, liquids, and area when shown concrete examples (Tomlinson-Keasey, Eisert, Kahle, Hardy-Brown, & Heasey, 1979). Though capable of complex problem solving, these concrete operational students display a less abstract understanding of material than formal operational students. For instance, they show a tendency to justify their answers, as they will explicitly state logical rules used when solving problems (Harris & Butterworth, 2002). Though they display proficiency with concrete objects and theories, they have difficulty dealing with more abstract concepts.

Formal operational students possess many of the same logical abilities as concrete operational students, but they gain the ability to deal with abstract concepts (Inhelder & Piaget, 1958). This is incredibly important in the context of teaching chemistry, as many core chemistry concepts are abstract in nature (Williams, Turner, Debreuil, Fast, & Berestiansky, 1979). It is not surprising, therefore, that formal operational students perform better in chemistry classes than do concrete operational students (Bunce & Hutchinson, 1993; Nicoll & Francisco, 2001). For this reason, Mwamwenda suggests that formal operational thinking is instrumental for students to succeed in studies at the university level (2008).

In the context of this study, transitional students are students who are just beginning to display formal operational thinking ability. Though they are no longer completely concrete thinkers, they are not completely formal either. Transitional students may display formal operational thinking when dealing with certain problems, but rely on concrete operational thinking when solving others.

Given the influence that cognitive development has on students' ability to comprehend chemistry concepts, it is important to compare Treatment and Control sections to ensure that they do not differ significantly in class composition with respect to cognitive development. This is also important to analyze since the Learning Cycle, which is taught to students during the course of this study, can be considered a formal concept. Cognitive development in this study is measured using the Test of Scientific Reasoning, or TOSR (Lawson, 1978).

For a more detailed analysis on Piaget's theory of cognitive development, see *Piaget for Educators* by Bybee and Sund (1982).

The Learning Cycle

The Learning Cycle model is a student-oriented, inquiry based instructional strategy. Students in Learning Cycle classes are involved in both the collection of data and the invention of concepts. This is most commonly done in a laboratory environment. It is because of this that Learning Cycle classes are considered "guided-inquiry" teaching environments. When compared to the more traditional "verification" laboratories (in which students verify a principle they were already introduced to in lecture), students in guided-inquiry laboratories discover the concept for themselves during the course of the laboratory (Allen, Barker, & Ramsden, 1986).

In the Learning Cycle, students first perform experiments designed to introduce them to a new scientific concept in a process called "exploration". The exploration phase is typically the laboratory, though other techniques, such as verbal presentations, have also been shown to be effective explorations (Schwab, 1963). Following exploration, students are then led to derive the concept themselves in a Socratic questioning process termed “concept invention”. The course instructor, using student data from the laboratory, guides students towards the formation of a scientific theory. They are then given the opportunity to apply the concept to other related areas via additional activities in the “concept application” phase. The concept application phase can take a number of forms, including worksheets on the newly created concept and laboratory investigations on a related topic to the created concept. The concept application phase of one Learning Cycle can, in turn, become the exploration phase of a new Learning Cycle to teach a new concept.

The Learning Cycle offers a number of benefits to verification laboratories. First and foremost, students instructed using the Learning Cycle have been shown to have a more complete understanding of chemistry than students who were instructed using verification laboratories (Renner, Abraham, & Birnie, 1985). While formal operational students perform equally well in verification courses and Learning Cycle courses (Ward & Herron, 1980), concrete operational students learn better in Learning Cycle classes than verification ones (Purser & Renner, 1983). Students also retain information better in Learning Cycle classes than verification ones (Schneider & Renner, 1980). In addition, students in Learning Cycle classes are more likely than students in verification classes to develop formal operational thinking ability (Carlson, 1975).

There is evidence to suggest that students are aware of differences between teaching styles. A study by Abraham suggests that students have substantially different opinions on laboratories based on the manner of instruction, with students in verification laboratories believing that the major goal of the laboratory was to develop skills and techniques in chemistry, while students in guided-inquiry style laboratories believe that they designed their own experiments and needed evidence to back up their conclusions in laboratory (1982). Teaching students directly about the Learning Cycle, therefore, might serve as an even more effective means of altering their perception of the laboratory.

Instruction on the Learning Cycle will necessitate additional instruction on its theoretical underpinnings, namely the nature of science and learning theory. As the following sections show, both may prove advantageous to general chemistry students.

Students in this study are enrolled in a Learning Cycle style general chemistry class. Treatment students are instructed on both chemistry concepts and on the Learning Cycle itself, including its theoretical basis.

For additional information on the Learning Cycle, see *A Theory of Instruction: Using the Learning Cycle to Teach Science Concepts and Thinking Skills* by Lawson, Abraham, and Renner (1989) and "The Learning Cycle approach as a strategy for instruction in science" by Abraham (1998).

Nature of Science

Upon its construction, one of the primary purposes of the Learning Cycle was to mimic the nature of scientific discovery (Bodner, 1986). Much like the exploration, concept invention, and concept application phases of the Learning Cycle, scientific discovery is a cyclical process in which experimentation reveals new knowledge. This new knowledge can reveal new questions that can be answered by continuing research. In fact, Matson and Parsons report that an accurate understanding of the way science is actually conducted, along with scientific inquiry, are necessary for effective science education (2006).

The term “nature of science” broadly describes the ways in which scientific discovery occurs and the characteristics of scientific knowledge. Though the exact definition is the subject of some debate, McComas, Clough, and Almazroa state that the following represent an international consensus view of the nature of science (1998):

- Scientific knowledge, while durable, has a tentative character.
- Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism.
- There is no one way to do science (therefore, there is no universal step-by- step scientific method).
- Science is an attempt to explain natural phenomena.
- Laws and theories serve different roles in science, therefore students should note that theories do not become laws even with additional evidence.
- People from all cultures contribute to science.
- New knowledge must be reported clearly and openly.
- Scientists require accurate record keeping, peer review and replicability.
- Observations are theory-laden.
- Scientists are creative.
- The history of science reveals both an evolutionary and revolutionary character.

- Science is part of social and cultural traditions.
- Science and technology impact each other.
- Scientific ideas are affected by their social & historical milieu.

Many organizations support the spread of knowledge of the nature of science as a way of countering scientific illiteracy in the United States. Of note is the congressional charter of the American Chemical Society, which states that one of the organization's goals is to increase scientific literacy in the United States (Baum, 2011).

Ironically, despite the fact that the Learning Cycle has found increasing use in classrooms of every educational level and is built around a model of scientific discovery, students increasingly show misconceptions about the nature of science (Abd-El-Khalick & Lederman, 2000). Students may be exposed to misconceptions from a variety of sources. Science textbooks, while intended to be a source of information, frequently perpetuate myths about the nature of science (Gould, 1998). Misconceptions may also come from science teachers themselves, who frequently possess misconceptions about the nature of science or misuse science concepts (Matson & Parsons, 1998; Parsons, Matson, & Quintanar, 2002).

Misconceptions born in the classroom are prone to proliferation in society as a whole. Ziman suggests that the role that society attributes to science and scientists is "largely determined by the way in which scientific knowledge is presented in the classroom" (1980). Even proper instruction of the nature of science does not necessitate that students will have a more accurate understanding of its principles. Preece suggests that many misconceptions about the nature of science are innate to individuals, and that they may appear regardless of education (1984). While the widespread nature of misconceptions is disappointing as it applies to broader social implications about the importance of science in today's society, it also has dire implications for education. Research has shown that students with a better understanding of the nature of science have a deeper understanding of science concepts (Songer & Linn, 1991).

Inquiry science teaching methods, such as the Learning Cycle, are widely believed to be best methods for helping students develop an understanding of the nature of science (Lawson, 2003). Despite the fact that students who are instructed using a Learning Cycle instruction model are experiencing a microcosm of science every day in their chemistry class, they often possess poor understanding of how science actually functions. The students, it would appear, do not realize that the very class that they are in is modeled after how science actually works. If they were made aware of the fact that they themselves were experiencing a similar process, they could derive information from their chemistry class to have a greater understanding of the nature of science.

Teaching the nature of science in the context of a lesson on the Learning Cycle could be an effective strategy. Lederman suggests that the most influential factor for students' perceptions of the nature of science is "instructional behaviors, activities, and decisions implemented within the context of a lesson" (1992). For this model to be effective, however, the nature of science would need to be explored in class. Indeed, examining the Learning Cycle without examining its theoretical basis is akin to "examining the products of science without experiencing the process of science" (Marek, 2009).

Such a benefit is not unprecedented. French and Russell report that graduate teaching assistants have a better understanding of the nature of scientific discovery after teaching Learning Cycle classes (2002). However, no research currently exists concerning how undergraduate students perform in a Learning Cycle classroom when they have knowledge of the Learning Cycle and the theory supporting it. It is possible that teaching students about the Learning Cycle could significantly improve their perceptions of the nature of science, and in the process, improve their understanding of chemistry concepts.

In this study, student opinions on the nature of science are assessed using the Views on Science and Education Questionnaire, or VOSE (Chen, Development of an instrument to assess views on nature of science and attitudes toward teaching science, 2006; Chen, Views on Science and education (VOSE) questionnaire, 2006).

Metacognition

Besides being based on the scientific model of discovery, the Learning Cycle also has ties to learning theories. More specifically, the Learning Cycle is derived from the model of learning proposed by Jean Piaget (Abraham & Renner, 1986).

Piaget proposed a 3-stage model, often referred to as Piaget's mental functioning model, to describe the process by which students learn and process information (Piaget, 1970). Piaget's mental functioning model consists of the assimilation, accommodation, and organization phases (Ginsburg & Opper, 1979).

Students are first exposed to new facts in a process called assimilation. Any presentation of new information, whether it be through direct communication from another person or through observations by the student as a result of his actions, may be considered assimilation. If this new information contradicts the student's prior knowledge, he enters a state known as disequilibrium. To again become equilibrated, the student must accommodate his existing knowledge to account for this new information. This is known as the accommodation phase. The final phase, organization, occurs when the student solidifies connections in his mind between the newly accommodated information and other pre-existing knowledge. The exploration, concept invention, and application phases of the Learning Cycle are analogous to the assimilation, accommodation, and organization phases, respectively, in Piaget's model of learning (Abraham & Renner, 1986). To effectively instruct students on the nature of the Learning Cycle, it is essential that they be instructed in its theoretical basis, including Piaget's mental functioning model. Student knowledge of this model could increase their metacognition.

Though educational psychologists do have a strict definition for metacognition, it can be defined loosely as the ability to think about thinking (Boström & Lassen, 2006). It is widely considered to be instrumental in developing deeper, more durable learning in students (Rickey & Stacy, 2000). A review by Wang, Haertel, and Walberg suggests that metacognition is among the most important factors influencing how well students learn science (1990). Metacognition consists of two components: awareness and action. Awareness describes cognizance of one's own mental processes and action refers to one's ability to self-regulate these mental processes (Wilen & Phillips, 1995).

One area of debate to researchers about metacognition concerns its subject specificity. On one hand, metacognition can be viewed as a set of general skills that can compensate for deficiency in a given area (Schraw, 1998). Kuhn and Dean, on the other hand, state that metacognition is a skill that allows students to use a problem solving strategy for a unique problem in a unique context and extrapolate its use to a similar, but different, problem (2004). In this way metacognition can be said to be subject specific. This situation is complicated by the fact that division lines between different subjects can be tenuous, making it difficult to effectively isolate individual subjects (Larkin, 2009). In the end, researchers have attempted to separate metacognition into both subject specific and non-subject specific capacities (Kendall, Ryan, Weeks, Alpert, Schwols, & Moore, 2008). Metacognition in the context of this study focuses on chemistry-problem solving ability specifically.

Since Piaget's mental functioning model is so closely related to the Learning Cycle, teaching students about how they learn both strengthens the theoretical basis for the Learning Cycle and serves as an introduction into the nature of the learning process. An introduction to the process of learning satisfies the awareness component of metacognition by making students aware of how they learn. The awareness component of metacognition is necessary before students are able to self-regulate their own mental processes. This additional content will not likely hinder students' comprehension of chemistry. Wilen and Phillips have shown that infusion, or teaching metacognition in the context of course material, can be an effective learning strategy for both course content and metacognition (1995).

The use of metacognition in Learning Cycle instruction is not uncommon. Process Oriented Guided Inquiry Learning (POGIL) is a teaching style that incorporates elements from both the Learning Cycle and metacognition (Hanson, 2006). Blank has also shown that students in a Learning Cycle ecology course with increased emphasis on metacognition experienced greater long-term restructuring of ecology understanding (2000). Of particular note to this study, it has been shown that increasing students' metacognition and understanding of the nature of science concurrently causes them to respond to questions in a more scientifically valid manner (Peters & Kitsantas, 2010). Instructing students on the nature of Piagetian learning theory could strengthen students' metacognition, which would also strengthen their ability to comprehend chemistry concepts.

In this study, students metacognition in chemistry will be analyzed using the Metacognitive Activities Inventory, or MCAI (Cooper & Sandi-Urena, 2009).

Linking Laboratory and Lecture

Alexander Smith's Heuristic Method, which forms the basis of modern chemistry instruction, states that the teaching of chemistry should be based primarily on the laboratory (DeBoer, 1991). Commonly, the laboratory section is taught in conjunction with a lecture section. One reason this teaching method is effective is because research suggests that student best learn scientific principles when exposed to these principles in multiple settings (Abraham, 2005).

Yet despite its pedagogical importance, a common student complaint about the laboratory portion of chemistry is that it seems irrelevant when compared to the lecture portion (Russell & Weaver, 2008). At first glance, these complaints seem paradoxical since many students enjoy the laboratory component more than the lecture component. For instance, in an informal survey of high school students, 70% reported that their favorite part of their high school chemistry classes was the laboratory (Gabel, 1999). Yet despite the pedagogical importance of the laboratory component and some students' enjoyment of it, the irrelevance with which some students view it causes many to not properly benefit from this instruction.

There are many underlying factors which could be responsible for this disconnect between students and the laboratory. Perhaps the most pervasive problem is students' tendency to view the laboratory and lecture components as two mutually exclusive entities (Gabel, 1999; Schultz, 2000). And when comparing the two components, students often feel that the laboratory is less useful. Some students believe that experiments lack a clear focus, while others feel that practical work is not enjoyable (Johnstone & Letton, 1988). This could be partly attributed to laboratory manuals, many of which are too procedural (Candruff & Reid, 2003). Many students are bothered by the chemicals used in laboratory, many of which they do not recognize and are therefore unable to relate to (Phelps, 1996). Whatever the reason, many students tend to undervalue the laboratory component and instead focus their energy on comprehending the lecture instead.

Instructors, who understand the reasons behind the lesson plan, often do not feel the need to justify the laboratory component to students. While instructors view the laboratory as a crucial step in the students' active learning process, students view the laboratory as busy work, or assignments lacking intellectual rigor and pedagogical rationale given just to occupy time (White, 2009). This lack of connection between students and instructors is visible in other areas. For example, students have a tendency to view observations in laboratory at a macroscopic level, while instructors are expecting them to examine observations from a microscopic viewpoint as in lecture (Johnstone, 1991).

Boud, et al. has suggested that an effective way of increasing the importance of the laboratory in the minds of the students is to clearly state the goals and objectives of the course (1986). If this transparency endows the laboratory section with a sense of importance in the eyes of the students, should it not therefore be extended to the method of instruction, the Learning Cycle? If students understand the pedagogical reason for the laboratory section, they are less likely to view it as busy work and more likely to view it as a worthwhile learning endeavor. Furthermore, by explaining the nature of the Learning Cycle, namely that observations made in laboratory lead to the creation of concepts used in lecture, students will better understand the pedagogical connection between these two components. When students better understand this connection, there is an increased likelihood that they will attempt to apply principles from laboratory to lecture and from lecture to laboratory, which could serve to create a deeper understanding of chemistry concepts.

In this study, student opinions of the lab and lecture are assessed using the Lab-Lecture Survey, or LLS. The LLS was created for this study, and is discussed in greater detail in Chapter III.

Chapter III

Research Methodology

Class Format

General chemistry at the university where this research was carried out consists of three class components: lecture, laboratory, and recitation. Lecture sections are taught by experienced lecturers with a doctoral degree in chemistry or a related field. Laboratory and recitation sections are taught by teaching assistants.

Teaching assistants are typically graduate students in chemistry or accomplished undergraduates in their last semester of study. Teaching assistants are required to attend a two day workshop before their first semester teaching general chemistry. The workshop contains instruction on the course structure as well as advice for first time teachers. New teaching assistants are also required to enroll in an education seminar during their first semester of teaching. This seminar is a one semester course which discusses teaching strategy and educational theory, and addresses practical teaching questions of the teaching assistants. Teaching assistants are typically responsible for teaching two lab sections and two linked recitation sections each semester.

Laboratory sections contain approximately 24 students and meet once a week. Students complete each experiment working in pairs, and each pair of students is responsible for turning in a single lab report for each experiment. The laboratory uses a

Learning Cycle instructional strategy characterized as open/guided inquiry (Abraham, 2005). A majority of experiments are guided-inquiry labs, in which students follow procedures in the lab manual and record observations. These observations later become the basis of the concept invention in the recitation section. However, there are several open-inquiry labs during the semester, in which students investigate a chemistry question with a procedure they invent. Since each pair of students is responsible for choosing a question to answer and creating the procedure, these experiments do not contain a formal concept invention phase during the recitation. Teaching assistants typically do not introduce new concepts during the laboratory section.

Recitation sections also contain approximately 24 students and meet once a week. The primary purpose of the recitation section is to discuss as a class what the students observed in lab and draw conclusions from it (concept invention), and to work in small groups on worksheets (concept application). Students may also ask questions pertaining directly to material covered in the lecture section.

The same students from the laboratory portion are grouped together in the recitation section. However, there is no correlation between laboratory and a student's lecture section, and it is common that a laboratory section will be made up of students from different lecture sections. Though students are allowed to ask questions during lecture, the size of the class typically precludes a large amount of student-instructor interaction. Student-instructor interaction is usually much greater in lab and recitation, where class size is much smaller.

Lecture sections are large (approximately 300 students). Lecture sections typically consist of either a computer based or chalkboard presentation of important concepts. Instructors also typically work through example problems similar to ones students will see on examinations. The lecture sections utilize a clicker system to encourage student involvement. The lecture portion of the classes does not explicitly discuss individual laboratory experiments, though students do discuss the concepts addressed in the recitation and laboratory components.

Laboratories and lecture sections are arranged so that students will perform experiments and invent concepts in recitation prior to seeing them in lecture. However, due to prior instruction in high school classes, many students enter general chemistry with some degree of familiarity of the concepts before seeing them in laboratory.

Sample

Students for this study were drawn from approximately 1200 students enrolled in general chemistry. The students are typically in their first semester of college when taking general chemistry. Of the approximately 50 laboratory sections of general chemistry, four were designated as treatment and four were designated as controls. Four teaching assistants were used for this study, with each being responsible for a single Treatment section and a single Control section. Assignment of Treatment and Control sections was random. Teaching assistants who were selected to participate in this study had taught general chemistry previously and had proven themselves to be effective instructors.

Instrumentation

Cognitive development was measured using the Test of Scientific Reasoning, or TOSR (Lawson, 1978). The 24 questions in the TOSR are paired, with one paired question asking for a likely formal observation and second asking for an explanation of the first paired question. Students must correctly answer both paired question to receive credit for the pair to minimize the effect of guessing, with a maximum total of 14 points. Students are classified into four groups based on score: formal operational (score 11-14), high transitional operational (score of 8-10), low transitional operational (5-7), and concrete operational (0-4).

The link between the lab and lecture was analyzed using a short survey, the Lab-Lecture Survey (LLS), that was created for this study. This survey consists of 8 statements evaluated on a 5-point Likert scale about the student's opinions on both the laboratory and lecture portion, and the connection they place between these two sections. A copy of the LLS can be found in Appendix B.

These questions probe the students' perceptions of the importance of the laboratory component of the course. They are constructed to discourage acquiescence, or students' tendency to agree with statements in surveys because they feel that is what is expected of them.

Student metacognition was analyzed using the Metacognitive Activities Inventory, or MCAI (Cooper & Sandi-Urena, 2009). The MCAI is specifically designed to test students' metacognitive ability in chemistry. It consists of 27 statements about chemistry problem-solving that students evaluate on a 5-level Likert scale. The MCAI's short length renders it useful for use with large numbers of students.

Student understanding of the nature of science was measured using the Views on Science and Education Questionnaire, or VOSE (Chen, Development of an instrument to assess views on nature of science and attitudes toward teaching science, 2006; Chen, Views on Science and education (VOSE) questionnaire, 2006). The VOSE is a collection of 84 statements about the nature of science that students rate for relative agreement on a 5-level Likert scale. Questions from the VOSE are grouped and averaged to assess their views on a number of topics of the nature of science. Topics analyzed include the following:

- Tentativeness of science
- Nature of observations
- Scientific methods
- Theories and laws
- Use of imagination
- Validation of scientific knowledge
- Subjectivity and objectivity

Unlike most nature of science evaluations which consist of free-form student writing, the Likert scale questions on the VOSE lend themselves well to large student populations. In addition to analyzing student opinions on these topics, the VOSE also assesses how students believe that these topics should be taught in a science classroom. Results from the VOSE may be analyzed two ways: by examining results from each subcategory separately, or by combining oppositional subcategories, using reverse values for subcategories that are given less priority by researchers. As individual views are not advocated in the treatment, each subcategory will be analyzed individually.

All instruments for this laboratory were adapted to be accessed using the Qualtrics online survey software. Administering these surveys online offers a number of advantages over a paper-and-pencil administration:

- Administering quizzes on Qulatrics accrues no additional fees for asking questions whereas paper-and-pencil tests accrue printing fees.
- An online quiz is more environmentally friendly than the paper-based alternative.
- The Qualtrics software automatically compiles data for all respondents, rendering manually reading the data moot.
- Administering quizzes electronically does not interfere with normal classroom instruction.
- Computer based quizzes are comparable to paper-based quizzes in evaluating students (Lee & Weerakoon, 2001).

Statistical analysis was completed using version 5.0 of the JMP statistical software. Graphs were generated using Microsoft Excel 2010.

The Learning Cycle Evaluation Worksheet (LCEW)

The Learning Cycle Evaluation Worksheet (LCEW) is an additional paper-based instrument that was created for this study and is designed to strengthen the concept of the Learning Cycle in the minds of the students. It is turned in by students in the Treatment group with every laboratory report. To serve as an effective reminder, the LCEW is designed to draw students' attention to the three phases of the Learning Cycle. It consists of three open-ended questions.

1. **Exploration**. What do you think are the most important observations from the exploration portions of this lab? Explain why you think these observations are important.
2. **Concept Invention**. What was the concept that you discovered in the exploration phase? What *specific* observations support this concept?
3. **Concept Application**. What are three uses of this concept in the area of chemistry that you can think of? Explain how the concept is used in your three applications. Your three uses can be things you learned about in lecture or ways you could use the concept in lab.

The first use of the LCEW is to serve as reminder to the students of the stages of the Learning Cycle. By drawing attention to the three phases and specifically asking questions from each of the three phases, it forces students to examine the phases and how they relate to each other during every laboratory. The LCEW is designed to highlight two of the core concepts of the Learning Cycle concerning the concept discovered:

concepts must be able to be justified by observations made in laboratory (questions 1 and 2) and concepts derived in laboratory should be extrapolated to other areas (question 3).

The LCEW is also designed to mimic the nature of scientific discovery. Most importantly, it emphasizes the importance of linking concepts with specific observations made in laboratory (question 2). This serves to emphasize McComas, Clough, and Almazroa's second statement concerning the nature of science, namely that scientific knowledge draws heavily from observation. It also indirectly satisfies their belief that the nature of science requires that knowledge be communicated clearly and openly.

In addition, the LCEW encourages student metacognitive processes. It causes students to think critically about their observations made in lab and to label what observations they think are important (question 1). The wording of this question encourages students to examine their thought processes and defend their choice of importance of a subjective ranking system. By causing students to examine their thought processes, it encourages metacognition.

The LCEW also addresses the connection between lab and lecture in the student's mind. Question 3 specifically mentions the lecture component as a source of potential uses of the concept of the laboratory. By asking students to connect the concept of the laboratory with the lecture component and think critically about this connection, the relationship between these two components of the course is reinforced.

Research Design

Four Treatment sections and four Control sections were randomly designated before the beginning of the semester. Four different teaching assistants were used in the study. Each was responsible for teaching a Treatment section and a Control section to minimize the effect of different teaching styles and abilities of the teaching assistants.

The study was explained to the teaching assistants prior to the beginning of the semester by the lead researcher. The teaching assistants had all previously attended an introductory course in the Learning Cycle and its importance; however, this information was reiterated to them at the introductory meeting as at least a year had passed for all four teaching assistants since they had taken it. Progress was monitored through weekly meetings and discussions between the four teaching assistants and the lead researcher.

One major concern of this study was when to begin instruction about the nature of the Learning Cycle: at the beginning or end of the semester. If the semester itself is viewed as an exploration phase of a Learning Cycle devoted to the nature of the Learning Cycle, the nature of science, and metacognition, it would follow that students should undergo concept invention after finishing the laboratory portion of the class near the end of the semester. However, there are problems with approaching instruction in this order. For example, students are more likely to focus on metacognition when they are specifically instructed to do so (Schraw, 1998). This would also have a detrimental effect on both students' conception of the importance of lab and their ability to effectively connect the lecture and laboratory components of the course until near the end of the course. For this reason, students were instructed on the Learning Cycle and its theoretical basis near the beginning of the semester, with continued instruction during the course of the semester.

Instruction occurred on weeks following examinations, as these recitation classes are typically shorter, given that students typically have fewer questions about the lecture material following examinations. The first laboratory of the semester was an exploration of the concept of density. Students measure the mass of aluminum cylinders with an analytical balance. They then measured the volume using water displacement in a graduated cylinder. Students compared the masses and volumes of six aluminum cylinders, and from the concept invention arrive at the conclusion that mass and volume are directly related in a concept called density. The following recitation period, students in both the Control and Treatment sections underwent a concept invention for density and worked in groups on an assignment about density.

Students in the Treatment group, however, are also asked to reflect on their experience in lab and recitation. They are then instructed on the nature of the Learning Cycle and told that there class will be taught using this method. This concept invention is administered by the teaching assistants responsible for teaching the classes.

Throughout the course of the semester, students in the Control and Treatment sections complete the same guided inquiry laboratories with the same laboratory reports. Students in the Treatment sections, however, are also given the Learning Cycle Evaluation Worksheet (LCEW) in conjunction with the lab report. During the course of the semester, the teaching assistants referred directly to the phases of the Learning Cycle, such as referring to the laboratory sessions as “explorations”. Once a month in recitation, students in the Treatment group receive an additional lecture over the nature of Learning Cycle and are given a short assignment over what they had learned. Learning cycle instruction was deliberately placed after exam weeks, when students typically have fewer questions about ongoing lecture material. Instruction of the Learning Cycle proceeded by the following schedule.

- First recitation: Overview of the Learning Cycle and a description of each phase.
- After Examination 1: Description of the Learning Cycle's basis on the nature of science.
- After Examination 2: Description of the Learning Cycle's basis on learning theory.
- After Examination 3: A review of the phases of the Learning Cycle and its relationship to the nature of science and learning theory.

Near the end of the semester, the TOSR, MCAI, LLS, and VOSE are made available to all students. Students are offered bonus points towards their grade in general chemistry for completing all four surveys. This incentive is designed to offset students' reluctance to complete an otherwise optional online quiz. Though all students in general chemistry were eligible to take the quizzes, only those students in Treatment and Control sections were analyzed.

Results were analyzed using single factor analysis of variance (ANOVA) for significant differences due to treatment alone, and with two-way ANOVA for interactive effects between treatment and cognitive development. A t-test was used for post-hoc analysis for questions with an interaction effect between TOSR score and treatment.

Chapter IV

Results

Only students who completed a majority of each of the four surveys (TOSR, LLS, MCAI, and VOSE) were included in the data analysis so that correlations could be drawn. In addition, students who provided multiple contradicting results for at least one quiz were excluded from data analysis. There were 108 students who met these requirements: 60 in the Treatment sections and 48 in the Control sections.

Results are summarized in tables with relevant statistics. Summary tables include degrees of freedom (the number of values that can vary in statistical calculations), sum of squares (the sum of all standard deviations, squared), mean square (the average standard deviation, adjusted for degrees of freedom), F-value (the value on the F-distribution that results from the test of Analysis of Variance on the data set), and p-value (the probability that the null hypothesis is true for the analyzed groups of data). In addition, tables are included with average values for groups based on section type (Treatment or Control) and TOSR division (top half or bottom half), and significant group differences (based on ANOVA results or post-hoc analysis).

Defining Significance

For this study, acceptable error was taken at 0.10 rather than 0.05, the most commonly used value for educational research. This value was chosen to minimize the effect of Type II errors.

Two types of error may be encountered when performing statistical analyses: Type I and Type II. A Type I error is characterized by incorrectly rejecting a true null hypothesis (a false positive), while a Type II error is marked by the failure to reject a false hypothesis (a false negative). While error of any kind should be minimized, a Type II error can be more detrimental to educational practice than is a Type I error.

The result of a Type II error is that an educational technique that is actually beneficial is erroneously found not to be. In the case of a Type I error, an educational technique that in fact makes no difference in instruction is found to be beneficial. The result of a Type I error is that students are taught using a method that is no more effective than other methods.

While a Type I error could cause the instructor to invest time changing to a methodology that is in fact no more effective than previous ones, this error has little effect on students' ability to learn the subject material as both methods are in fact equally effective. However, a Type II error would result in an instructor ignoring what is actually a beneficial teaching method. Though this error does not burden the instructor with changing teaching methodologies, students are deprived of instruction with a superior teaching method and thus have an inferior understanding of the subject material than they would otherwise have. Since the focus of education should be on students and their ability to learn, a Type II error can be considered worse from an educational standpoint than a Type I error. One way to minimize Type II errors is to accept higher p-values. As a result, p values less than or equal to 0.10 were accepted as significant for this study.

Test of Scientific Reasoning Results

The Test of Scientific Reasoning (TOSR) is a 24 question multiple choice survey used to evaluate student cognitive development (Lawson, 1978). TOSR scores can range from 0 to 14, with scores of 11 to 14 representing a formal operational student, scores of 5-10 representing transitional students, and scores of 0 to 4 representing concrete operational students.

Table 4.1: Summary of TOSR results

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Average Score	Treatment	1	12.87967	12.8797	1.8125	0.1811
	Residual	106	753.22218	7.1059		

	Source	Overall	Group Difference
Average Score	Control	6.4680851	No Main Effect
	Treatment	7.2622951	

Student responses show that there is not a significant difference in cognitive development between Treatment and Control sections (see table 4.1). Student distribution by cognitive development is shown in Table 4.2.

Table 4.2: Student Distribution by Cognitive Development

	Treatment	Control
Concrete Operational	26.2%	23.4%
Low Transitional	13.1%	29.8%
High Transitional	42.6%	38.3%
Formal Operational	18.0%	8.5%

Distributions are similar between Treatment and Control sections. The Treatment sections contain more formal operational and high transitional students and fewer low transitional students than the Control sections. Both Treatment and Control sections displayed overall higher cognitive development than the distribution of college students described by McKinnon and Renner of 50% concrete operational, 25% transitional, and 25% formal operational (1971).

Grade Analysis Results

Grade data for the 108 students in the Treatment and Control sections across the three main grade items (total exam points, total points in labs, and total recitation points) are summarized in tables 4.3 and 4.4. Tables 4.5 and 4.6 contain a breakdown of grade differences for lab experiments that did not incorporate the Learning Cycle Evaluation Worksheet (LCEW). Of the four teaching assistants in the study, one required the LCEW in treatment section for these labs. As a result, data from the teaching assistant's Control and Treatment sections were not included in the analysis, resulting in a sample size of 83 students (n_T=47, n_C=36) for these tables.

Table 4.3: ANOVA analysis of grade items

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Exams	Treatment	1	45.05	45.05	0.0112	0.9159
	Residual	106	426711.20	4025.58		
Lab Total	Treatment	1	1119.115	1119.11	4.9379	0.0284
	Residual	106	25023.802	226.64		
Recitation	Treatment	1	1.2295	1.2295	0.0637	0.8013
	Residual	106	2046.6502	19.3080		
Total Points	Treatment	1	1310.73	1310.73	0.1960	0.6588
	Residual	106	708746.90	6686.29		

	Source	Overall	Group Difference
Exams	Control	274.68085	No Main Effect
	Treatment	275.98361	
Lab Total	Control	135.63830	T > C
	Treatment	142.12115	
Recitation	Control	77.276596	No Main Effect
	Treatment	77.491803	
Total Points	Control	477.91915	No Main Effect
	Treatment	484.94590	

Table 4.4: Summary of open-inquiry labs

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
System Lab Total Points	Treatment	1	346.0318	346.032	7.3780	0.0081
	Residual	80	3742.0170	46.900		

	Source	Overall	Group Difference
Systems Labs Point Total	Control	50.319149	T > C
	Treatment	52.655738	

These results suggest that there is not a significant difference between Treatment and Control sections for exam grades, recitation grades, and total points in the class, while there is a significant difference for laboratory grades (see table 4.3). Grade differences for the laboratories may be expected, since the treatment in this study occurred in the laboratory and not the lecture. However, there is a difference in grade scales between Treatment and Control labs since Treatment students were graded on their completion of the LCEW for most laboratory grades. It should be noted that grade scales were equivalent for the open ended systems laboratories. For these systems labs, Treatment students display significantly higher grades than Control students for two of the three systems laboratories, as well as significantly higher grades overall for systems laboratories (see table 4.4).

Lab-Lecture Survey Results

Results from the Lab-Lecture Survey (LLS) are summarized in Table 4.5. The LLS is an eight question Likert scale quiz created to assess student opinions of the laboratory and lecture and assess the connection that students had between the two portions of the class. Students responded to statements in the LLS with varying levels of agreement to eight statements. A score of 5 corresponds to a response of “Strongly Agree”, and a score of 1 corresponds to a response of “Strongly Disagree”.

The intent of the LLS was to gauge how closely students linked the lab and lecture components of the course. Agreement with the first four statements corresponded to a closer linking of the lab and lecture. Likewise, a lack of agreement with the final four questions of the LLS more closely constituted a closer connection between the lab and lecture component of the course. The LLS Ratio is calculated by dividing the total possible points for all questions (or the inverted score in the case of the final four questions) by the score corresponding to complete connection between the lab and lecture (40). The LLS Ratio is meant to evaluate the overall connection between the laboratory and lecture sections of the course across all questions.

Table 4.5: Summary of LLS results for Treatment and Control sections

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
1	Treatment	1	0.55622	0.55622	0.4070	0.5249
	Residual	106	144.87897	1.36678		
2	Treatment	1	1.94479	1.94479	1.4437	0.2322
	Residual	106	142.79595	1.34713		
3	Treatment	1	3.25119	3.25119	3.1746	0.0777
	Residual	105	107.53386	1.02413		
4	Treatment	1	0.04346	0.04346	0.0348	0.8524
	Residual	106	132.47506	1.24976		
5	Treatment	1	0.13048	0.13048	0.0800	0.7778
	Residual	106	172.78619	1.63006		
6	Treatment	1	0.05973	0.05973	0.0440	0.8342
	Residual	106	143.79212	1.35653		
7	Treatment	1	1.145834	1.14583	1.3124	0.2546
	Residual	105	91.676596	0.87311		
8	Treatment	1	0.83673	0.83763	0.4954	0.4831
	Residual	106	179.04290	1.68908		
LLS Ratio	Treatment	1	0.0147318	0.014732	0.9822	0.3240
	Residual	104	1.5598673	0.014999		

	Source	Overall	Group Difference
1	Control	3.2978723	No Main Effect
	Treatment	3.442623	
2	Control	3.106383	No Main Effect
	Treatment	3.3770492	
3	Control	3.4347826	T > C
	Treatment	3.7868852	
4	Control	2.6808511	No Main Effect
	Treatment	2.7213115	
5	Control	3.2340426	No Main Effect
	Treatment	3.1639344	
6	Control	3.0638298	No Main Effect
	Treatment	3.0163934	
7	Control	3.8085106	No Main Effect
	Treatment	3.6000000	
8	Control	3.2978723	No Main Effect
	Treatment	3.4754098	
LLS Ratio	Control	0.5766304	No Main Effect
	Treatment	0.6004167	

LLS results suggest that Treatment students are significantly more likely than Control students to agree with question 3, “I used things that I learned in lecture to help me understand things I did in lab” (see table 4.5). Treatment and Control students did not have significantly different responses for any of the other 7 items, or the ratio overall.

Metacognitive Activities Inventory Results

The Metacognitive Activities Inventory (MCAI) is a 27 question survey designed to assess student metacognition in a chemistry context using a Likert Scale, with a score of 5 corresponding to a response of “Strongly Agree” and a score of 1 corresponding to a response of “Strongly Disagree” (Cooper & Sandi-Urena, 2009). A higher level of agreement corresponds to a more metacognitive response for all questions, with the exception of the final 8 questions in which a lower level of agreement is indicative of a more metacognitive response. The MCAI Ratio is calculated by dividing the total possible points for all questions (or the inverted score in the case of the final eight questions) by the score corresponding to complete connection between the lab and lecture (162) and multiplying by 100. An MCAI Ratio of 100 corresponds to the most metacognitive answers possible on all questions.

Student responses for Treatment and Control sections for the MCAI are summarized in Table 4.6. Correlations are analyzed between MCAI questions and treatment, cognitive development, and an interactive effect for treatment and cognitive development.

Table 4.6: Comparison of MCAI responses

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Ratio	Treatment	1	18.78932	18.78932	0.2517	0.6170
	TOSR	1	321.64167	321.64167	4.3094	0.0406
	Treatment * TOSR	1	217.42088	217.42088	2.9131	0.0912
	Residual	94	7015.8401	74.637		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Ratio	Control	73.289760	72.622222	72.892416	T TH > T BH
	Treatment	76.750299	71.170370	74.259259	

MCAI results suggest that students with more advanced cognitive development are significantly more likely to use metacognition than students with less advanced cognitive development. In addition, Treatment students with more advanced cognitive development are significantly more likely to display metacognition than Treatment students with low cognitive development.

Views on Science and Education Questionnaire Results

The Views on Science and Education Questionnaire (VOSE) evaluates student opinions on a number of subjects related to the nature of science, as well as students' attitudes towards teaching these areas. The VOSE analyzes both student opinions on the nature of science itself, as well as their opinions on the role of nature of science topics in the classroom. It consists of 85 Likert Scale questions, with a score of 5 corresponding to a response of "Strongly Agree" and a score of 1 corresponding to a response of "Strongly Disagree". Student views are interpreted by analyzing average scores for a question or set of questions. Subjects analyzed in the VOSE are listed below:

- Tentativeness of science
- Nature of observations
- Scientific methods
- Theories and laws
- Use of imagination
- Validation of scientific knowledge
- Subjectivity and objectivity

Some of these subjects were either discussed directly or indirectly addressed in the laboratory or lecture curriculum that students were exposed to, though not all were. This will be discussed in greater detail in Chapter V.

Results from the Views on Science and Education Questionnaire showed varying student opinions on the nature of science based on cognitive development, treatment, and a combination of these two factors.

Tentativeness of Science

While science is tentative in nature, the exact nature of its tentativeness is subject to some debate. Three principle models exist to describe the tentativeness of science: the revolutionary model, the evolutionary model, and a cumulative model incorporating aspects of the both the revolutionary and evolutionary models.

Table 4.7: VOSE Philosophy, Measure of Tentativeness

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Revolutionary (4A)	Treatment	1	1.0623090	1.0623090	1.2837	0.2598
	TOSR	1	6.4722325	6.4722325	7.8209	0.0062
	Treatment * TOSR	1	0.0244109	0.0244109	0.0295	0.8640
	Residual	103	85.237932	0.82755		
Cumulative (4B)	Treatment	1	1.1587843	1.1587843	1.5049	0.2227
	TOSR	1	7.1982169	7.1982169	9.3480	0.0028
	Treatment * TOSR	1	0.0361180	0.0361180	0.0469	0.8290
	Residual	103	79.313001	0.77003		
Evolutionary (4C)	Treatment	1	0.14894054	0.14894054	0.2544	0.6151
	TOSR	1	0.19207629	0.19207629	0.3281	0.5680
	Treatment * TOSR	1	0.03110457	0.03110457	0.0531	0.8182
	Residual	103	60.304492	0.585481		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Revolutionary (4A)	Control	3.8823529	3.4666667	3.6170213	TH > BH
	Treatment	3.7187500	3.2142857	3.4833333	
Cumulative (4B)	Control	2.9411765	3.2333333	3.1276596	BH > TH
	Treatment	3.0625000	3.5000000	3.2666667	
Evolutionary (4C)	Control	3.5294118	3.8000000	3.7021277	No Main Effect
	Treatment	3.6562500	3.8928571	3.7666667	

Student results suggest that students with high TOSR scores are significantly more likely to believe that scientific change is revolutionary in nature (see table 4.7). Students with low TOSR scores are significantly more likely to believe that scientific change is cumulative in nature. These trends are analyzed in more detail in Chapter V. Neither treatment, cognitive development, nor an interactive effect between these factors affects student opinion on the evolutionary view of scientific tentativeness.

Nature of Observations

Observations in science are theory-laden. When performing experiments, scientist cannot and should not separate themselves from their previous scientific knowledge.

Table 4.8: VOSE philosophy, Nature of Observations

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Theory Laden (8A, 8B, 8E)	Treatment	1	0.21678842	0.21678842	1.2154	0.2728
	TOSR	1	0.05937085	0.05937085	0.3329	0.5652
	Treatment * TOSR	1	0.53685149	0.53685149	3.0098	0.0857
	Residual	104	18.550119	0.178367		
Theory Independent (8C, 8D)	Treatment	1	0.8293875	0.8293875	1.3307	0.2513
	TOSR	1	0.0776179	0.0776179	0.1245	0.7249
	Treatment * TOSR	1	1.0691486	1.0691486	1.7154	0.1932
	Residual	104	64.821317	0.623282		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Theory Laden (8A, 8B, 8E)	Control	3.5098039	3.2000000	3.3120567	C TH > C BH C TH > T TH
	Treatment	3.1770833	3.2873563	3.2295082	
Theory Independent (8C, 8D)	Control	2.8823529	3.1666667	3.0638298	No Main Effect
	Treatment	3.3593750	3.1206897	3.2459016	

Control students with high TOSR scores are significantly more likely than Treatment students with high TOSR scores or Control students with low TOSR scores to believe that scientific observations are based on theory (see table 4.8). These trends are analyzed in more detail in Chapter V. Treatment, TOSR score, and cognitive development do not significantly alter student opinions on whether observations should be made independently of scientific theory.

Scientific Methods

Science is a flexible process that can follow a multitude of different formats. Though it is often taught in science classes, there is no Universal Scientific Method that scientists follow when researching.

Table 4.9: VOSE philosophy, Scientific Methods

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
The Universal Scientific Method (9A, 9B, 9F)	Treatment	1	0.43266820	0.43266820	1.2754	0.2614
	TOSR	1	0.04054349	0.04054349	0.1195	0.7303
	Treatment * TOSR	1	0.01626287	0.01626287	0.0479	0.8271
	Residual	104	35.282209	0.339252		
Diverse Methods (9C, 9D, 9E)	Treatment	1	0.00636105	0.00636105	0.0151	0.9024
	TOSR	1	0.8966070	0.8966070	0.2132	0.6452
	Treatment * TOSR	1	0.01835123	0.01835123	0.0436	0.8349
	Residual	104	43.740657	0.420583		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
The Universal Scientific Method (9A, 9B, 9F)	Control	3.7450980	3.6000000	3.6524823	No Main Effect
	Treatment	3.7500000	3.8275862	3.7868852	
Diverse Methods (9C, 9D, 9E)	Control	2.8627451	2.7666667	2.8014184	No Main Effect
	Treatment	2.8750000	2.7701149	2.8251366	

Students, regardless of treatment, TOSR score, and the interaction of treatment of TOSR score, overall believe that science follows the universal scientific method (see table 4.9). Students are less likely to believe that science is a diverse process, and their responses were not affected by treatment, TOSR score, or the interaction of these two factors. These pervasive misconceptions are addressed in more detail in Chapter V.

Theories and Laws

Despite being based on experimental observations, scientific laws and theories are created by scientists themselves and do not exist as an immutable truth of the universe to be discovered. Laws and theories themselves are two different types of information, and neither is more certain.

Table 4.10: VOSE philosophy, Theories and Laws (Epistemology)

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Discovered (5A, 5B, 6A, 6C)	Treatment	1	0.0165713	0.0165713	0.0407	0.8405
	TOSR	1	0.2149680	0.2149680	0.5281	0.4690
	Treatment * TOSR	1	1.3404628	1.3404628	3.2930	0.0725
	Residual	104	42.335297	0.407070		
Invented (5D, 5E, 5F, 6D, 6E)	Treatment	1	0.20363038	0.20363038	0.3468	0.5572
	TOSR	1	0.35962590	0.35962590	0.6125	0.4357
	Treatment * TOSR	1	0.17546847	0.17546847	0.2988	0.5858
	Residual	103	60.480707	0.587191		
Discovered or Invented (5C, 6C)	Treatment	1	0.4748735	0.4748735	0.8250	0.3659
	TOSR	1	0.0368643	0.0368643	0.0640	0.8007
	Treatment * TOSR	1	1.9505993	1.9505993	3.3886	0.0685
	Residual	103	59.205258	0.575632		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Discovered (5A, 5B, 6A, 6C)	Control	3.7794118	3.7583333	3.7659574	None
	Treatment	3.9296875	3.6551724	3.7991803	
Invented (5D, 5E, 5F, 6D, 6E)	Control	2.9176471	2.7933333	2.8382979	No Main Effect
	Treatment	2.9483871	2.9379310	2.9433333	
Discovered or Invented (5C, 6C)	Control	3.3529412	3.4655172	3.4239130	None
	Treatment	3.4062500	3.1379310	3.2786885	

Table 4.11: VOSE philosophy, Theories and Laws (Comparison)

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Laws are more certain (7A, 7B)	Treatment	1	1.8131090	1.8131090	3.0201	0.0852
	TOSR	1	3.5074708	3.5074708	5.8424	0.0174
	Treatment * TOSR	1	1.4353598	1.4353598	2.3909	0.1251
	Residual	103	61.836326	0.60035		
Different types of ideas (7C, 7D)	Treatment	1	0.36847570	0.36847570	0.7702	0.3822
	TOSR	1	0.16629971	0.16629971	0.3476	0.5568
	Treatment * TOSR	1	0.04368521	0.04368521	0.0913	0.7631
	Residual	104	49.757369	0.478436		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Laws are more certain (7A, 7B)	Control	4.0294118	3.9166667	3.9574468	C > T TH > BH
	Treatment	3.9843750	3.4642857	3.7416667	
Different types of ideas (7C, 7D)	Control	2.6470588	2.5666667	2.5957447	No Main Effect
	Treatment	2.6718750	2.7413793	2.7049180	

Treatment and cognitive development have a significant interaction effect for determining whether students believe scientific knowledge is discovered alone, or can be both discovered and invented (see table 4.10). However, post-hoc analysis did not reveal a significant difference between groups. Treatment students are more likely than Control students to believe that laws are more certain than theories (see table 4.11). Though there is no interaction effect, students with high TOSR scores are also significantly more likely than students with low TOSR scores to believe that laws are more certain than theories. The relationship between theories and laws is not directly addressed in either Treatment or Control sections, which casts doubt on the reliability of these trends. They will be analyzed in more detail in Chapter V.

Use of Imagination

Imagination is an integral part of scientific discovery. Scientists utilize imagination during the entire scientific process, from designing experiments to analyzing results.

Table 4.12: VOSE philosophy, Use of Imagination

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Yes (3A, 3B)	Treatment	1	0.0402354	0.0402354	0.0447	0.8330
	TOSR	1	2.2059157	2.2059157	2.4494	0.1207
	Treatment * TOSR	1	0.5746266	0.5746266	0.6381	0.4263
	Residual	102	91.859416	0.90058		
No (3C, 3D, 3E)	Treatment	1	0.1334195	0.1334195	0.2451	0.6216
	TOSR	1	0.7622609	0.7622609	1.4004	0.2393
	Treatment * TOSR	1	1.3791418	1.3791418	2.5338	0.1145
	Residual	104	56.607656	0.544304		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Yes (3A, 3B)	Control	3.5588235	3.2241379	3.3478261	No Main Effect
	Treatment	3.5000000	3.1724138	3.3416667	
No (3C, 3D, 3E)	Control	2.6666667	2.7888889	2.7446809	No Main Effect
	Treatment	2.5833333	3.0344828	2.7978142	

Treatment, TOSR score, and the interactive effect between these two factors did not significantly affect students' opinions on the role of imagination in science (see table 4.12). Overall, students showed a slight tendency to believe that imagination is important in the nature of science.

Validation of Scientific Knowledge

Though science strives to be a process influenced only by empirical evidence, in actuality a variety of factors can influence which theories are accepted by the scientific community. Possible sources of influence include the existing scientific paradigm, the simplicity of the theory, the reputation of the researchers, and the researchers' intuition.

Table 4.13: VOSE Philosophy, Validation of scientific knowledge

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Empirical Evidence (1A, 1H)	Treatment	1	0.8016017	0.8016017	1.5389	0.2176
	TOSR	1	0.8703282	0.8703282	1.6708	0.1990
	Treatment * TOSR	1	1.214473	1.214473	2.3315	0.1298
	Residual	104	54.174301	0.520907		
Paradigm (1C, 1F)	Treatment	1	6.4306387	6.4306387	11.9718	0.0008
	TOSR	1	0.0992178	0.0992178	0.1847	0.6682
	Treatment * TOSR	1	0.1382243	0.1382243	0.2573	0.6130
	Residual	104	55.863678	0.53715		
Parsimony (1D)	Treatment	1	2.9016448	2.9016448	3.3565	0.0698
	TOSR	1	0.0305045	0.0305045	0.353	0.8514
	Treatment * TOSR	1	0.7970570	0.7970570	0.9220	0.3392
	Residual	103	89.040887	0.86447		
Authority (1E)	Treatment	1	0.0151664	0.0151664	0.0158	0.9003
	TOSR	1	1.0426235	1.0426235	1.0846	0.3001
	Treatment * TOSR	1	0.8337366	0.8337366	0.8673	0.3539
	Residual	101	97.086850	0.961256		
Intuition (1G)	Treatment	1	0.0002539	0.0002539	0.0002	0.9883
	TOSR	1	1.1897655	1.1897655	1.0048	0.3185
	Treatment * TOSR	1	1.5782535	1.5782535	1.3329	0.2509
	Residual	104	123.14056	1.18404		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Empirical Evidence (1A, 1H)	Control	2.5294118	2.8166667	2.7127660	No Main Effects
	Treatment	2.8437500	2.8793103	2.8606557	
Paradigm (1C, 1F)	Control	3.2647059	3.1166667	3.1702128	C > T
	Treatment	2.7187500	2.6379310	2.6803279	
Parsimony (1D)	Control	2.4705882	2.3333333	2.3829787	C > T
	Treatment	2.1290323	1.9655172	2.0500000	
Authority (1E)	Control	2.7647059	3.0666667	2.9574468	No Main Effects
	Treatment	2.9354839	2.9629630	2.9482759	
Intuition (1G)	Control	2.5882353	2.3666667	2.4468085	No Main Effects
	Treatment	2.2187500	2.6551724	2.4262295	

Treatment students are significantly less likely than Control students to believe that the existing paradigm and the parsimony of the findings can influence their acceptance (see table 4.13). This trend is analyzed in more detail in Chapter V. Treatment, TOSR score, and the interactive effect between these two factors did not significantly affect students' perceptions of the roll of empirical evidence, authority of the researchers, or intuition.

Subjectivity and Objectivity

Though scientists attempts to remain objective in research, they are unavoidably influenced by their own personal biases and characteristics. A number of factors, including the simplicity of the theory, the authority of individual researchers, the existing scientific paradigm, the researcher's personal characteristics, the influence of society on the researcher, the researcher's imagination, and the methodology used can influence the conclusions that scientists come to.

Table 4.14: VOSE Philosophy, Subjectivity and Objectivity (Subjectivity), Part I

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Parsimony (1D)	Treatment	1	2.9016448	2.9016448	3.3565	0.0698
	TOSR	1	0.0305045	0.0305045	0.353	0.8514
	Treatment * TOSR	1	0.7970570	0.7970570	0.9220	0.3392
	Residual	103	89.040887	0.86447		
Authority (1E)	Treatment	1	0.0151664	0.0151664	0.0158	0.9003
	TOSR	1	1.0426235	1.0426235	1.0846	0.3001
	Treatment * TOSR	1	0.8337366	0.8337366	0.8673	0.3539
	Residual	101	97.086850	0.961256		
Paradigm (1C, 1F, 8A, 8B)	Treatment	1	3.0196105	3.0196105	10.2252	0.0018
	TOSR	1	0.0411065	0.0411065	0.1392	0.7098
	Treatment * TOSR	1	0.0150863	0.0150863	0.0511	0.8216
	Residual	104	30.712208	0.29531		
Personal factors (1G, 8A, 15A, 15D, 15H)	Treatment	1	0.12241356	0.12241356	0.6172	0.4339
	TOSR	1	0.05592466	0.05592466	0.2820	0.5966
	Treatment * TOSR	1	0.13572155	0.13572155	0.6843	0.4100
	Residual	103	20.428563	0.198336		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Parsimony (1D)	Control	2.4705882	2.3333333	2.3829787	C > T
	Treatment	2.1290323	1.9655172	2.0500000	
Authority (1E)	Control	2.7647059	3.0666667	2.9574468	No Main Effects
	Treatment	2.9354839	2.9629630	2.9482759	
Paradigm (1C, 1F, 8A, 8B)	Control	3.3088235	3.1666667	3.2180851	C > T
	Treatment	2.8281250	2.9017857	2.8729508	
Personal factors (1G, 8A, 15A, 15D, 15H)	Control	3.3764706	3.3466667	3.3574468	No Main Effects
	Treatment	3.2875000	3.2785714	3.2833333	

Table 4.15: VOSE Philosophy, Subjectivity and Objectivity (Subjectivity), Part II

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Sociocultural influence (2A, 2B, 15B, 15C)	Treatment	1	0.60362956	0.60362956	1.4503	0.2312
	TOSR	1	0.39150925	0.39150925	0.9406	0.3344
	Treatment * TOSR	1	0.11548948	0.11548948	0.2775	0.5995
	Residual	104	43.287101	0.416222		
Imagination (3A, 3B)	Treatment	1	0.0402354	0.0402354	0.0447	0.8330
	TOSR	1	2.2059157	2.2059157	2.4494	0.1207
	Treatment * TOSR	1	0.5746266	0.5746266	0.6381	0.4263
	Residual	102	91.859416	0.90058		
Methodology (9D)	Treatment	1	0.00667281	0.00667281	0.0086	0.9262
	TOSR	1	0.16718122	0.16718122	0.2157	0.6433
	Treatment * TOSR	1	0.40871785	0.40871785	0.5274	0.4693
	Residual	104	80.597615	0.774977		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Sociocultural influence (2A, 2B, 15B, 15C)	Control	3.6617647	3.5750000	3.6063830	No Main Effects
	Treatment	3.6171875	3.3103448	3.4713115	
Imagination (3A, 3B)	Control	3.5588235	3.2241379	3.3478261	No Main Effects
	Treatment	3.5000000	3.1724138	3.3416667	
Methodology (9D)	Control	2.2352941	2.3666667	2.3191489	No Main Effects
	Treatment	2.4687500	2.1379310	2.3114754	

Table 4.16: VOSE Philosophy, Subjectivity and Objectivity (Neutral)

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Neutral (1B)	Treatment	1	0.02137920	0.02137920	0.0220	0.8825
	TOSR	1	0.72514724	0.72514724	0.7450	0.3901
	Treatment * TOSR	1	0.47395929	0.47395929	0.4869	0.4869
	Residual	104	101.23411	0.973405		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Neutral (1B)	Control	3.2941176	3.0333333	3.1276596	No Main Effects
	Treatment	3.2187500	3.1379310	3.1803279	

Table 4.17: VOSE Philosophy, Subjectivity and Objectivity (Objectivity), Part I

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
No influence of socioculture (2C, 2D, 15F)	Treatment	1	0.35483141	0.35483141	0.6392	0.4258
	TOSR	1	0.00303405	0.00303405	0.0055	0.9412
	Treatment * TOSR	1	0.05405827	0.05405827	0.0974	0.7556
	Residual	104	57.730068	0.555097		
Use no imagination (3C, 3E)	Treatment	1	0.2089517	0.2089517	0.2960	0.5876
	TOSR	1	0.6997944	0.6997944	0.9913	0.3217
	Treatment * TOSR	1	1.7512984	1.7512984	2.4809	0.1183
	Residual	104	73.413898	0.70590		
Based on experimental facts (5B, 6B, 8D)	Treatment	1	0.2834877	0.2834877	0.8390	0.3618
	TOSR	1	0.0411280	0.0411280	0.1217	0.7279
	Treatment * TOSR	1	1.2259375	1.2259375	3.6283	0.0596
	Residual	104	35.139415	0.337879		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
No influence of socioculture (2C, 2D, 15F)	Control	2.9411765	2.8666667	2.8936170	No Main Effects
	Treatment	2.9895833	3.0344828	3.0109290	
Use no imagination (3C, 3E)	Control	2.7058824	2.7833333	2.7553191	No Main Effects
	Treatment	2.5937500	3.0862069	2.8278689	
Based on experimental facts (5B, 6B, 8D)	Control	3.5098039	3.5555556	3.5390071	None
	Treatment	3.7500000	3.5287356	3.6448087	

Table 4.18: VOSE Philosophy, Subjectivity and Objectivity (Objectivity), Part II

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
No influence of personal beliefs (8C, 15E, 15I)	Treatment	1	0.4374852	0.4374852	1.2213	0.2717
	TOSR	1	1.2365032	1.2365032	3.4518	0.0660
	Treatment * TOSR	1	0.2012795	0.2012795	0.5619	0.4552
	Residual	103	36.896456	0.358218		
Methodology (8E, 9A, 9B)	Treatment	1	0.36141903	0.36141903	1.2303	0.2699
	TOSR	1	0.79831547	0.79831547	2.7176	0.1023
	Treatment * TOSR	1	0.20607043	0.20607043	0.7015	0.4042
	Residual	104	30.551158	0.293761		
Overall (1A, 1H, 15G)	Treatment	1	0.41077557	0.41077557	1.1828	0.2793
	TOSR	1	0.20954262	0.20954262	0.6034	0.4391
	Treatment * TOSR	1	0.55298235	0.55298235	1.5922	0.2098
	Residual	104	36.118898	0.347297		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
No influence of personal beliefs (8C, 15E, 15I)	Control	2.5490196	2.8666667	2.7517730	BH > TH
	Treatment	2.7604167	2.9523810	2.8500000	
Methodology (8E, 9A, 9B)	Control	3.8823529	3.5444444	3.6666667	No Main Effects
	Treatment	3.8125000	3.8045977	3.8087432	
Overall (1A, 1H, 15G)	Control	2.8039216	3.0222222	2.9432624	No Main Effects
	Treatment	3.0312500	3.0804598	3.0546448	

Treatment students are significantly less likely than Control students to believe that scientists can be influenced by paradigm and parsimony in scientific research (see table 4.14). Though there is a significant interaction effect between treatment and student TOSR score, groups do not display differences in post-hoc analysis (see table 4.17). Students with low TOSR scores are more likely to believe that scientists are not influenced by their personal beliefs when conducting research than students with high TOSR scores (see table 4.18). These trends are analyzed in more detail in Chapter V. Treatment, TOSR score, and an interactive effect between these two factors do not significantly affect student opinion on the role of authority, sociocultural influence, imagination, and methodology (see tables 4.14-4.18).

Teaching the Tentativeness of Science

Science is a tentative process. While durable, scientific knowledge can change over time as new discoveries are made.

Table 4.19: VOSE Teaching Attitudes, Tentativeness

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Teaching the tentativeness of scientific knowledge (12A, 12B)	Treatment	1	0.0249196	0.0249196	0.0879	0.7674
	TOSR	1	1.1148475	1.1148475	3.9346	0.0499
	Treatment * TOSR	1	0.2420177	0.2420177	0.8541	0.3575
	Residual	104	29.467906	0.283345		
Avoid teaching the tentativeness of scientific knowledge (12C, 12D, 12E)	Treatment	1	0.0669114	0.0669114	0.1301	0.7191
	TOSR	1	3.3938600	3.3938600	6.5969	0.0116
	Treatment * TOSR	1	0.0414623	0.0414623	0.0806	0.7771
	Residual	103	52.989557	0.51446		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Teaching the tentativeness of scientific knowledge (12A, 12B)	Control	4.1176471	4.0833333	4.0957447	TH > BH
	Treatment	4.1875000	3.9642857	4.0901639	
Avoid teaching the tentativeness of scientific knowledge (12C, 12D, 12E)	Control	2.0392157	2.1555556	2.1134752	BH > TH
	Treatment	1.9687500	2.2857143	2.1166667	

Students with high TOSR scores are significantly more likely to believe that instructors should teach the tentativeness of science than students with low TOSR score (see table 4.19). This trend is analyzed in more detail in Chapter V. Treatment has no effect on student opinions on whether or not the tentativeness of scientific knowledge should be taught.

Teaching the Nature of Observations

Though observations should remain as objective as possible, they are also theory-laden by their very nature.

Table 4.20: VOSE Teaching Attitudes, Nature of Observations

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Training students to make objective observations (11A, 11B, 11C)	Treatment	1	0.00624331	0.00624331	0.0096	0.9221
	TOSR	1	0.06118056	0.06118056	0.0943	0.7594
	Treatment * TOSR	1	0.58479149	0.58479149	0.9010	0.3447
	Residual	104	67.504422	0.649081		
Revealing the theory-laden nature of observations (11D, 11E)	Treatment	1	0.00701187	0.00701187	0.0078	0.9298
	TOSR	1	0.14308899	0.14308899	0.1594	0.6906
	Treatment * TOSR	1	0.03506710	0.03506710	0.0391	0.8437
	Residual	104	93.386339	0.897946		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Training students to make objective observations (11A, 11B, 11C)	Control	3.0196078	3.0555556	3.0425532	No Main Effects
	Treatment	3.0729167	3.0229885	3.0491803	
Revealing the theory-laden nature of observations (11D, 11E)	Control	3.1470588	3.2666667	3.2234043	No Main Effects
	Treatment	3.2656250	3.1206897	3.1967213	

Treatment, TOSR score, and the interactive effect between these factors do not significantly affect student perception on how the nature of observations should be taught in science classes (see table 4.20).

Teaching Scientific Methods

Science does not operate by a set method. Rather, it is a diverse process that can change based on the needs of the researcher and the demands of the research.

Table 4.21: VOSE Teaching Attitudes, Scientific Methods

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Teaching the universal scientific method (10A, 10B, 10C, 10D, 10E, 10F)	Treatment	1	0.44268037	0.44268037	1.5381	0.2177
	TOSR	1	0.07011957	0.07011957	0.2436	0.6227
	Treatment * TOSR	1	0.82729598	0.82729598	2.8744	0.0930
	Residual	103	29.645273	0.287818		
Encouraging different methods (10G, 10H, 10I)	Treatment	1	0.71151640	0.71151640	1.5664	0.2135
	TOSR	1	0.00256663	0.00256663	0.0057	0.9402
	Treatment * TOSR	1	0.00452376	0.00452376	0.0100	0.9207
	Residual	104	47.241420	0.45244		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Teaching the universal scientific method (10A, 10B, 10C, 10D, 10E, 10F)	Control	3.8431373	3.7988506	3.8152174	None
	Treatment	3.6822917	3.6666667	3.6748634	
Encouraging different methods (10G, 10H, 10I)	Control	2.5098039	2.5333333	2.5248227	No Main Effects
	Treatment	2.7708333	2.5977011	2.6885246	

Though treatment and TOSR score have a significant interaction effect for determining whether or not instructors should teach the universal scientific method, no group displayed significant difference through post-hoc analysis (see table 4.21) .

Treatment students with low TOSR scores are less likely than other students to believe that the Universal Scientific Method should be taught. These trends are analyzed in more detail in Chapter V.

Teaching Theories and Laws

While theories and laws are both forms of scientific knowledge, laws are no more certain than theories. A theory does not become a law with additional evidence.

Table 4.22: VOSE Teaching Attitudes, Theories and Laws

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Teaching the relationship between theories and laws (13A, 13B)	Treatment	1	0.0111626	0.0111626	0.0277	0.8682
	TOSR	1	1.7160335	1.7160335	4.2529	0.0417
	Treatment * TOSR	1	0.0065296	0.0065296	0.0162	0.8990
	Residual	103	41.560409	0.403499		
Avoid teaching the relationship (13C, 13D)	Treatment	1	0.2929475	0.2929475	0.4885	0.4862
	TOSR	1	1.2346580	1.2346580	2.0587	0.1543
	Treatment * TOSR	1	1.3245924	1.3245924	2.2086	0.1403
	Residual	104	62.372996	0.59974		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Teaching the relationship between theories and laws (13A, 13B)	Control	4.0312500	3.8333333	3.9021739	TH > BH
	Treatment	4.0000000	3.8275862	3.9180328	
Avoid teaching the relationship (13C, 13D)	Control	2.5882353	2.7333333	2.6808511	No Main Effects
	Treatment	2.5468750	3.0000000	2.7622951	

Students with high TOSR scores are more likely than those with low TOSR scores to believe that instructors should teach the relationship between theories and laws (see table 4.22). This trend is analyzed in more detail in Chapter V. Treatment did not significantly alter student perception on the importance of teaching the relationship between theories and laws.

Teaching Subjectivity and Objectivity

While they attempt to remain as objective as possible, scientists are influenced by subjective factors, such as personal factors the sociouclutural influences, when conducting research.

Table 4.23: VOSE Teaching Attitudes, Subjectivity and Objectivity: Teaching Subjectivity

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Personal factors (14A, 14D)	Treatment	1	0.9079342	0.9079342	2.1988	0.1412
	TOSR	1	2.3294602	2.3294602	5.6413	0.0194
	Treatment * TOSR	1	0.1927257	0.1927257	0.4667	0.4960
	Residual	102	42.118775	0.412929		
Sociocultural influences (14B, 14C)	Treatment	1	0.55179593	0.55179593	1.4676	0.2285
	TOSR	1	0.17581492	0.17581492	0.4676	0.4956
	Treatment * TOSR	1	0.02374631	0.02374631	0.0632	0.8021
	Residual	102	38.351487	0.375995		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Personal factors (14A, 14D)	Control	4.0294118	3.7666667	3.8617021	TH > BH
	Treatment	3.9062500	3.5000000	3.7203390	
Sociocultural influences (14B, 14C)	Control	3.7941176	3.7931034	3.7934783	No Main Effects
	Treatment	3.7656250	3.5357143	3.6583333	

Table 4.24: VOSE Teaching Attitudes, Subjectivity and Objectivity: Emphasizing Objectivity

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
No influence of personal beliefs (14E)	Treatment	1	2.5261620	2.5261620	2.5366	0.1143
	TOSR	1	4.2360636	4.2360636	4.2535	0.0417
	Treatment * TOSR	1	0.0383253	0.0383253	0.0385	0.8449
	Residual	103	102.57682	0.99589		
No influence of socioculture (14F)	Treatment	1	0.4064809	0.4064809	0.4372	0.5099
	TOSR	1	1.3167763	1.3167763	1.4164	0.2367
	Treatment * TOSR	1	0.1392221	0.1392221	0.14164	0.6996
	Residual	103	95.757921	0.929689		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
No influence of personal beliefs (14E)	Control	2.4705882	2.7666667	2.6595745	BH > TH
	Treatment	2.5625000	3.3214286	2.9166667	
No influence of socioculture (14F)	Control	2.8235294	2.9000000	2.8723404	No Main Effects
	Treatment	2.4375000	3.0357143	2.7166667	

Table 4.25: VOSE Teaching Attitudes, Subjectivity and Objectivity: value free

	Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-value
Value free in sciences courses (14G)	Treatment	1	0.1917937	0.1917937	0.2660	0.6071
	TOSR	1	1.6349683	1.6349683	2.2676	0.1352
	Treatment * TOSR	1	0.3693498	0.3693498	0.5123	0.4758
	Residual	103	74.264065	0.721010		

	Source	Top Half TOSR	Bottom Half TOSR	Overall	Group Differences
Value free in sciences courses (14G)	Control	2.5294118	2.4000000	2.4468085	No Main Effects
	Treatment	2.4375000	2.5714286	2.5000000	

Students with high TOSR scores are significantly more likely than those with low TOSR scores to believe that instructors should emphasize the importance of personal factors (see table 4.23). Students with low TOSR scores are significantly less likely than those with high scores to believe that instructors should avoid teaching the importance of personal beliefs (see table 4.24). These trends are analyzed in more detail in Chapter V. Treatment, TOSR score, and the interactive effect between treatment and TOSR score did not significantly influence student perception on the importance of teaching sociocultural influences in science classes (see tables 4.23-4.25).

VOSE Summary

Significant differences between students perceptions of the nature of science based on either treatment, cognitive development, or a combination of these factors are summarized below.

- Tentativeness of science—Students with high TOSR scores are more likely to believe that scientific change is revolutionary in nature, while those with low TOSR scores favor the cumulative view.
- Nature of observations—Control students with high TOSR scores are more likely than Control students with low TOSR scores and Treatment students with high TOSR scores to believe that observations are based on theory.
- Scientific methods—No significant differences were observed.
- Theories and laws—Treatment and TOSR score have a significant interactive effect in determining student's opinion on whether scientific knowledge is discovered, or can be both discovered and invented. Treatment students, as well as those students with high TOSR scores, are more likely to believe that laws are more certain than theories.
- Use of imagination—No significant differences were observed.
- Validation of scientific knowledge—Treatment students are less likely than Control students to believe that paradigm or parsimony could influence the validation of new scientific knowledge.
- Subjectivity and objectivity—Treatment students are less likely than Control students to believe that scientists are influenced by paradigm and parsimony. Treatment and TOSR score have a significant interactive effect in determining if

students believe that scientific knowledge is based on experimental facts. Students with low TOSR scores are more likely to believe that scientists can be influenced by their personal beliefs.

Significant differences between students perceptions on how the nature of science should be taught based on either treatment, cognitive development, or a combination of these factors are summarized below.

- Teaching the tentativeness of science—Students with high TOSR scores are more likely to believe that instructors should teach the tentativeness of science.
- Teaching the nature of observations—No significant difference was observed.
- Teaching scientific methods—Treatment and TOSR score have a significant interactive effect for determining if students believe that instructors should teach the universal scientific method.
- Teaching theories and laws—Students with high TOSR scores are more likely to believe that instructors should teach the relationship between theories and laws.
- Teaching subjectivity and objectivity—Students with high TOSR scores are more likely to believe that instructors should discuss the role of personal factors.

Chapter V

Discussion and Conclusions

Discussion

The discussion will be organized around the five principle methods of data collection in this study: the Test of Scientific Reasoning (TOSR), grade data, the Lab-Lecture Survey (LLS), the Metacognitive Activities Inventory (MCAI), and the Views on Science and Education Questionnaire (VOSE).

Test of Scientific Reasoning (TOSR)

Since cognitive development has strong correlation with performance in general chemistry (Rickey & Stacy, 2000), it was important to establish that the Treatment and Control section had similar distributions of cognitive development so that effects of the treatment could be analyzed. Average TOSR score was slightly higher in the Treatment section (6.590) than the Control (5.894). However, the difference between the two was not statistically significant [$\underline{F}$ (1, 106) = 1.813, p = 0.1811), which suggests that the Treatment and Control sections are equivalent. Further evidence for the equivalence of the Treatment and Control sections can be found in student grade data. Exam grades for Treatment students do vary significantly from those of Control students [$\underline{F}$ (1, 108) = 0.0112, p = 0.9159). The non-significant difference between TOSR scores for Treatment and Control students, combined with the non-significant difference between student exam scores, suggests that the Treatment and Control students are equivalent in composition.

Beyond being used as a test of section equivalence, cognitive development was found to have a significant effect on student views for a number of areas, which are discussed in detail in the following sections.

Grade Items

General chemistry grades consist primarily of three areas: standardized exams, laboratory grades, and recitation grades. Among these categories, the only significant grade difference between Treatment and Control sections is in laboratory grades [F (1, 105) = 4.938, p= 0.0284]. However, the Learning Cycle Evaluation Worksheet (LCEW), which was included as a component of the treatment, was graded for students in Treatment sections for all guided-inquiry labs. Since the scales for these guided-inquiry labs are different in Treatment and Control sections, the validity of this comparison can be called into question. Though this trend suggests that Treatment students perform better on all laboratories than Control students, it is helpful to examine those labs that did not require the LCEW.

Students in general chemistry are required to complete two types of laboratories: guided and open-inquiry. Treatment students are required to complete the LCEW for all guided-inquiry labs as a portion of the required grade. However, Treatment students are not required to complete the LCEW for the open-inquiry labs, as these lab reports do not have a structured concept invention phase during recitation. Treatment students perform significantly better than Control students on open-inquiry labs [$\underline{F}$ (1, 82) = 7.3780, p= 0.0081]. This suggests that treatment can significantly improve student performance on laboratory assignments.

The ability of Treatment students to perform better on laboratories than Control students is consistent with informal comments made by the teaching assistants involved with this study. As grades serve as an approximation of a student's total comprehension of the subject material, a variety of explanations likely exist for this trend. Metacognition, which was found to be higher for Treatment students with high TOSR scores, is a possible cause for students with more formal cognitive development. This trend is examined in greater detail in the Metacognitive Activities Inventory Results section.

This increase in laboratory grades, however, is observed independently of cognitive development, meaning that concrete operational students in the Treatment performed better on laboratory assignments than did concrete operational Control students. Clearly, something beyond metacognition is responsible for the increased student performance. Results from the Lab-Lecture Survey indicate that a likely explanation could be students' use of information from the lecture in the laboratory. This trend is examined in greater detail in the Lab-Lecture Survey Analysis section.

Lab-Lecture Survey (LLS)

The Lab-Lecture Survey (LLS) suggests that overall Treatment students have similar opinions on the connection between the laboratory and lecture portions of the class to Control students [F (1, 106) = 0.9822, p = 0.3240]. The exception to this is question 3, "I used things that I learned in lecture to help me understand things I did in lab", where Treatment students display significantly greater agreement than Control students [F (1, 107) = 3.1746, p = 0.0777].

While Treatment students are more likely to report they draw on information from lecture in lab, they are not more likely than Control students to report that they draw on information from lab to use in lecture [F (1, 108) = 1.4437, p = 0.2322]. These student self-assessments are consistent with grade data, where Treatment students perform significantly better on lab assignments than Control students, but do not perform significantly better on exams.

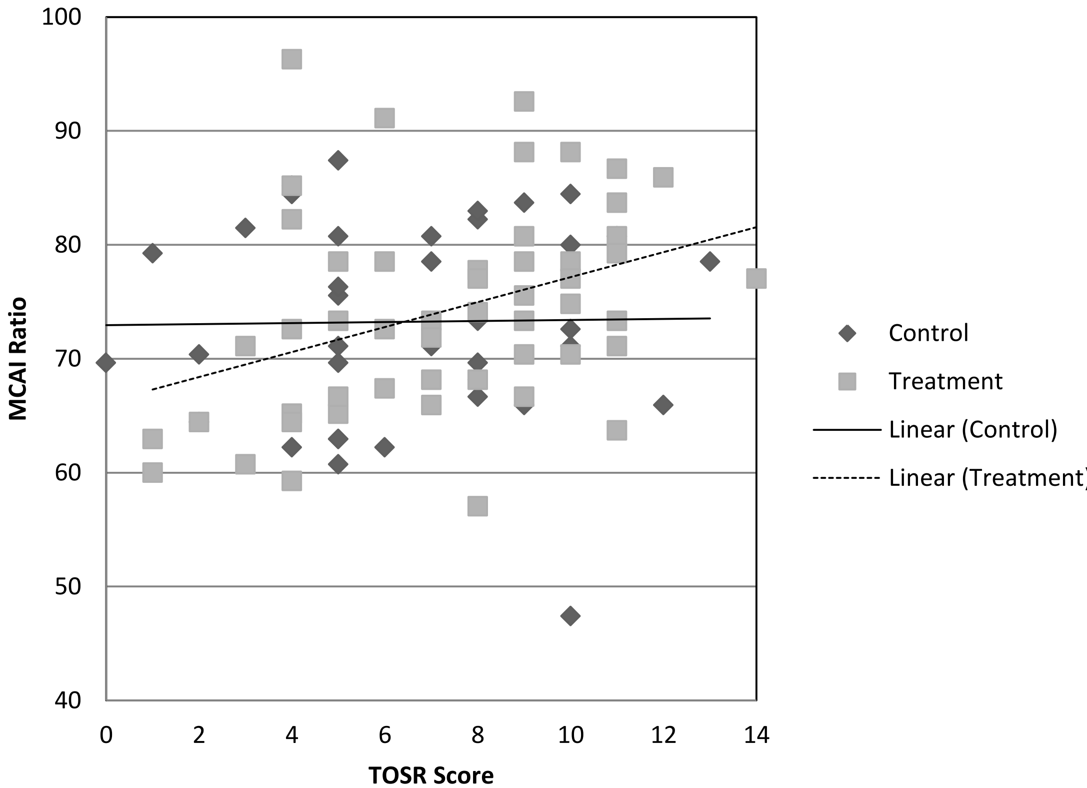
The third question of the Learning Cycle Evaluation Worksheet (LCEW) specifically asks students to relate the concept invented in lab to other areas in chemistry, including topics discussed specifically in lecture, so this is likely a major contributor to this increased use of lecture material by students in the laboratory. It is important to note that students were not specifically asked to draw upon information from lab in the lecture portion of the class, as the treatment was completely localized in the recitation and lab portions of the class. Therefore, students seem to be able to effectively link certain aspects of different portions of the class, but only when they are specifically asked to do so.

Metacognitive Activities Inventory (MCAI)

Multivariate ANOVA analysis was performed on MCAI results with TOSR score and Treatment as the analyzed variables. TOSR score has a significant interaction with MCAI ratio [$F(1, 98) = 4.3094$, $p = 0.0406$]. As the MCAI Ratio serves as indicator of overall metacognitive capabilities, this suggests that students with more advanced cognitive development are also more likely to have advanced metacognition. Paris and Winograd suggest that metacognition is "both a product and a producer of cognitive development", so a correlation between these two factors is not surprising (1990).

Overall, there is a significant interactive effect between TOSR score and Treatment [$F(1, 98) = 2.9131$, $p = 0.0912$]. Treatment students with high TOSR scores are significantly more likely than Treatment students with low TOSR scores to possess advanced metacognition.

Graph 5.1: MCAI Ratio vs. TOSR Score



As shown in Graph 5.1, treatment only seems to have a beneficial effect on student metacognition for students who score at least a 6 on the TOSR. This score corresponds to a low transitional student in intellectual development. Below this threshold, students do not receive a benefit to metacognition. Transitional students, who are only partially formal operational, did display increased metacognition, but the benefit is greater the more formal a student's thought processes are.

As the Learning Cycle might be considered as conceptually abstract, students who have not developed formal operational thinking ability may be less able to understand it (Cantu & Herron, 1978). Students who utilize strictly concrete operational thinking, therefore, seem to be unable to fully understand instruction of the Learning Cycle, and are therefore unable to benefit from instruction on its theoretical basis.

Hacker, Bol, and Keener caution that it is difficult to extrapolate metacognitive differences in the laboratory section to the classroom setting, as conditions that influence metacognition may differ significantly in each setting (2008). Grade data seems to suggest that this increased metacognition may be localized exclusively on the laboratory. Increased metacognition is known to be correlated with increased academic performance (Wang, Haertel, & Walberg, 1990). However, grades between Treatment and Control students were significantly higher for Treatment students on laboratory assignments and not on standardized exams, suggesting that this increased metacognition may only be used by students in the laboratory.

A possible explanation for this trend is the fact that instruction on the Learning Cycle in this study did not occur in the lecture section of the class. Despite the fact that this instruction was designed to explain the relationship between these two components, it would seem that students are unable to relate metacognitive processes to the lecture portion of the class without direct instruction during the lecture portion. It is worth noting that instructors of the lecture sections do not specifically emphasize metacognition during instruction of the lecture sections, further lending credence to this explanation.

Views on Science and Education Questionnaire (VOSE)

As the teaching style of the instructor is the single most important factor influencing how students view the nature of science (McComas & Almazroa, 1998), it is not surprising that teaching students about the Learning Cycle had an influence on their understanding of the nature of science. Treatment, cognitive development, and a combination of these two factors appeared to significantly affect certain aspects of student perceptions of the nature of science. The aspects of the nature of science analyzed by the VOSE are listed below.

- Tentativeness of science
- Nature of observations
- Scientific methods
- Theories and laws
- Use of imagination
- Validation of scientific knowledge
- Subjectivity and objectivity

While none of these areas are directly addressed during the treatment, it is assumed that students will be able to infer aspects of the nature of science simply from understanding that they are experiencing a microcosm of how science actually operates. However, a lack of explicit discussion on the nature of theories and laws likely means that treatment will not affect perception of this area, as the VOSE investigates rote understanding of these topics that is unlikely to be inferred by students.

The VOSE survey also analyzes how students believe that the nature of science should be taught to other students. Results for both sets of analyses are reported below.

Measure of Tentativeness

Scientific knowledge, while durable, is also tentative in nature and subject to change as new information is uncovered. And while most students grasp this central aspect of the nature of science, they differ in the reasons why they believe knowledge is tentative (Aikenhead, Fleming, & Ryan, 1987). The tentative nature of science is best represented by the “revolutionary” view of Thomas Kuhn (1970) and the “evolutionary” view of Karl Popper (1998). Kuhn’s revolutionary view argues that scientific change is a process, with long periods of little change punctuated by sudden drastic changes of thought (paradigm shifts). On the other hand, Popper’s evolutionary view argues that science changes in a linear fashion, with old information slowly and gradually being replaced by new information. The VOSE includes a third category to describe a student’s view on tentativeness called “cumulative”, which states that scientific tentativeness can be described by a combination of these two models.

Treatment did not significantly affect student perception of scientific tentativeness, though cognitive development did. Students with high TOSR scores were more likely to believe that scientific progress is revolutionary than were students with low TOSR scores, regardless of treatment [$F(1, 107) = 7.8209$, $p = 0.0062$].

Cognitive development also had a significant effect on the cumulative opinion of the tentativeness of science. Students with high TOSR scores were less likely than those with low TOSR scores to advocate a cumulative view of scientific tentativeness [$F(1, 107) = 9.3480$, $p = 0.0028$].

Though there was not a significant trend for the evolutionary view of scientific tentativeness alone, the cumulative view is a consolidation of both the evolutionary and revolutionary view. Between the revolutionary and cumulative view, students with a TOSR score greater than 5 were more likely to believe in the revolutionary view of scientific tentativeness alone compared to cumulative view. As this score corresponds to an early transitional student, it can be concluded that students with some formal operational thinking ability are more likely to advocate the revolutionary view alone, whereas purely concrete operational students are more likely to support a mixed revolutionary-evolutionary approach. Put another way, though all students have a tendency to believe in the revolutionary view of scientific tentativeness, students are more likely to believe that this operates in tandem with the evolutionary theory as TOSR score decreases. The explanation for this distinct difference could be due to a number of factors.

In the Learning Cycle labs in this study, a single concept was taught for each experiment. Due to the nature of the guided-inquiry labs, students are working towards a predetermined goal, a specific concept to be taught. As the Concept Invention occurred in the recitation period for every experiment at repeating intervals, it is logical to conclude that students would favor the revolutionary view of science over the evolutionary one, as knowledge was invented suddenly at regular intervals to them. Only students with formal operational reasoning ability will be able to fully appreciate the tentativeness of science (Flick & Lederman, 2004). Formal students, then, are more likely to develop the opinion that scientific change happens at intervals, rather than slowly over time, than concrete operational students, since they were better able to understand the processes by which they operated in class.

Interestingly, treatment did not significantly affect student perception of either the revolutionary view [$F (1, 107) = 1.2837$, $p = 0.2598$], the cumulative view [$F (1, 107) = 1.5049$, $p = 0.2227$], or the evolutionary view [$F (1, 107) = 0.2544$, $p = 0.6151$] of scientific tentativeness. Students develop these perceptions strictly based on cognitive development, with direct instruction on the Learning Cycle proving to have little effect on their perceptions of these views.

TOSR score was also the primary factor in determining how students believed that tentativeness should be approached in science instruction. Students with high TOSR scores are significantly more likely than those with low scores to believe that instructors should teach the tentative nature of science [$F (1, 108) = 3.9346$, $p = 0.0499$].

When analyzed with student perceptions on tentativeness, two main groups of students are apparent:

1. Students who believe that scientific change is revolutionary in nature. They tend to have higher TOSR scores, and believe that instructors should teach the tentativeness of science.
2. Students who believe that scientific knowledge is both revolutionary and evolutionary in nature. They tend to have lower TOSR scores, and believe that instructors should not teach the tentativeness of science.

Comparing the two groups of students, formal operational students possess a more narrowly defined vision of scientific tentativeness. They believe that change occurs in sudden intervals, and that this change should be taught to students. Concrete operational students seem to have a broader definition of how science changes and are less likely to believe that this process should have a place in the classroom. The broad views of these students, coupled with their comparative reluctance to think that instructors should teach the tentativeness of science, suggest that these students do not have an adequate understanding of the tentativeness of science. Given the abstract nature of both the revolutionary and evolutionary theories of scientific tentativeness, it makes sense that concrete operational students would have difficulty understanding these areas.

Nature of Observations

Though scientists attempt to make observations as objective as possible, it is impossible to completely eliminate the observer's prior knowledge, training, experiences and expectations (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Scientific observations, therefore, are said to be theory-laden, since they are made with previous knowledge about the surrounding scientific theory.

Control students with high TOSR scores are significantly more likely than Control students with low TOSR scores and Treatment students with low TOSR scores to believe that scientific observations are theory-laden [$F(1, 108) = 3.0098$, $p = 0.0857$]. Control students with low TOSR scores and all Treatment students display nearly identical agreement with this statement. Regardless of treatment and cognitive development, most students believe that scientific observations are influenced by theories.

Control students with high TOSR scores, therefore, display fewer misconceptions about the nature of observations than other students. Since students with more advanced cognitive development are more likely to have an advanced understanding of chemistry concepts, it is likely that the effect of TOSR score is a direct result of these students' own tendencies when making observations in lab. Since these students better understand the concepts taught in class, they are more likely to use them when making observations.

Treatment appears to have a negative effect on student conceptions of observations, causing students with high TOSR scores to nearly identical interpretations of scientific observations as students with low TOSR scores. Formal operational students are more likely to understand the nuances of the instruction pertaining to formal concepts like the nature of science and the Learning Cycle. Formal operational Treatment students, therefore, seem to have taken from instruction on the nature of the Learning Cycle that outside knowledge should not be used when making observations. Given that instruction on the Learning Cycle discusses how to derive knowledge from observations, but does not specifically address the role of previous knowledge in observations, these students seem to believe that using outside knowledge would go against the objective aspect of the nature of science.

Theories and Laws

Though they are often misunderstood by the general population, scientific theories and laws are different. A scientific law is a statement that describes what has already been observed and can predict what will be seen (Carnap, 1998). Simply put, laws are descriptive generalizations. A scientific theory, on the other hand, is an explanation of a particular phenomenon and its associated laws (American Association for the Advancement of Science, 1993). Though laws and theories have substantial supporting information based on experimental fact, they are both human constructs that are invented by scientists, not immutable truths to be discovered. As laws and theories are both human creations and simply different forms of knowledge, neither is more true, and a theory can never become a law.

TOSR Score and Treatment had a significant interactive effect for student perceptions on the epistemology of scientific knowledge. Both factors appears to affect students perception that knowledge is discovered only [$F(1, 108) = 3.2930$, $p = 0.0725$], and that it can be either discovered or invented [$F(1, 107) = 3.3886$, $p = 0.0685$]. However, post-hoc analysis did not show a significant difference between groups of students for either of these results. This may suggest that student opinions on the epistemology of scientific knowledge may be subject to a large amount of variance. This seems plausible given that students results vary significantly based on the interaction of TOSR score and treatment for the "discovered" and "discovered or invented" category, but not for the "invented" category alone [$F(1, 107) = 0.2988$, $p = 0.5858$]. Another possible explanation of this trend could be related the relatively high average responses. Most students showed significant agreement that scientific knowledge is discovered, but the maximum score for this item was limited to 5 because of the Likert scale format. It is possible that this maximum score is responsible for the lack of difference between groups observed through post-hoc analysis.

Independently of treatment and TOSR score, by and large most students agreed that scientific knowledge was discovered, not invented. As this fact is one of the more challenging aspects to teach about the nature of science (Chen, Development of an instrument to assess views on nature of science and attitudes toward teaching science, 2006), that most students believed that scientific knowledge can be, at least in part, discovered directly is not surprising.

In addition, both treatment and TOSR score have an effect on student perception of the certainty of laws and theories. Treatment students are less likely than Control students to believe that laws are more certain than theories [$F (1, 107) = 3.0201$, $p = 0.0852$]. Though there is no significant interactive effect, students with high TOSR scores are also more likely than those with low TOSR scores to believe that laws are more certain than theories [$F (1, 107) = 5.8424$, $p = 0.0174$]. In the end, regardless of treatment and cognitive development, most students believe that laws are more certain than theories.

The difference between laws and theories, as well as the difference between scientific and colloquial laws and theories, is widely misunderstood. For example, many non-scientists believe that since evolution is a theory, it is not scientifically rigorous and amounts to little more than a "dubious notion" (Moore, 1984). In fact, the debate concerning evolution is so prevalent in popular discourse and political discussions in America, that many students enter class with misconceptions about scientific theories and laws (Pennock, 2004). Indeed, scientific misconceptions in popular culture often have a more powerful impact on one's understanding of science and scientists than does formal science education (Riper, 2003). It is possible, therefore, that the reason most students believe that laws are more certain than theories is due to these previously held misconceptions. This could also explain why students with higher TOSR scores, on average, have greater misconceptions about theories and laws than those with low TOSR scores. It is possible that since the misconceptions surrounding scientific laws and theories are so widespread, this difference is due to familiarity with societal misconceptions. Formal operational thinkers may be more likely to be familiar with the debate (and misconceptions) surrounding evolution, and therefore more likely to be influenced by this prior knowledge.

At first glance, the significant decrease in misconceptions among Treatment students is surprising, since theories and laws are never directly addressed during instruction of the Learning Cycle. However, it could be this absence of information that is the cause of these students' more accurate understanding of theories and laws. Though they were not specifically told that scientific theories do not become laws, Treatment students were instructed on how science operates. Since theories and laws were not mentioned directly during instruction, students are more likely to assume that they are in fact not a part of how science operates. Overall, even Treatment students, on average, believed that laws are more certain than theories. However, giving students instruction on how science operates appears to offer a significant advantage to improving their perception of this relationship.

While both treatment and TOSR score are important for predicting student opinion on the relationship between theories and laws, only TOSR score is important for determining student opinions on whether or not this relationship should be taught. Students with high TOSR scores were more likely than other students to believe that instructors should teach the relationship between theories and laws than other groups of students [F (1, 107) = 4.2529, p = 0.0417]. Overall, students of all phases cognitive developments analyzed believe that instructors should teach the relationship between theories and laws.

While students with high TOSR scores are more likely to have misconceptions about theories and laws than those with low TOSR scores, they are also more likely to believe that this relationship should be taught. This is further evidence on how pervasive the misconceptions surrounding scientific theories and laws are. Since these students have a more certain view that theories can become laws, they are apparently also more certain that this relationship should be taught.

Validation of Scientific Knowledge

In theory, knowledge is accepted by the scientific community based strictly on its empirical merits. In actuality, however, a variety of other factors may influence the acceptance of new information, including simplicity of the new theory, prestige of the researchers, and its relationship to the currently accepted paradigm (Chen, Development of an instrument to assess views on nature of science and attitudes toward teaching science, 2006).

Treatment students were found to be less likely than Control students to believe that the current paradigm could influence the acceptance of new knowledge [F (1, 108) = 11.9718, p = 0.0008].

Treatment students were also less likely than Control students to believe that parsimony could influence the acceptance of new information [$F (1, 107) = 3.3565$, $p = 0.0698$]. Cognitive development did not have a significant effect on either paradigm or parsimony.

In the cases of both Treatment and Control students, perceptions of the influence of paradigm and parsimony varied wildly from strong agreement to strong disagreement. Treatment students had significantly greater misconceptions about the role of paradigm and parsimony in the validation of scientific knowledge than did Control students. As cognitive development did not have a significant effect, this difference is due completely to instruction on the Learning Cycle.

The treatment did not explicitly discuss the effect that parsimony and paradigm had in scientific validation. The students were instructed that the Learning Cycle was constructed to be based on how science actually operated. In the Concept Invention phase, the existing views of scientists and the simplicity of the concept invented were never discussed. Rather, the concept was created strictly using observed facts. Knowledge of the process itself is necessary for students to reach this conclusion, since other than having knowledge of the process, Concept Invention proceeded exactly the same in the Treatment and Control sections. Treatment students are left, therefore, with a more idealized view of science than those in the Control section. Since the Learning Cycle they experienced was based strictly on the theory of scientific validation rather than the reality, students were left with the erroneous understanding that science functions in an idealized fashion.

Subjectivity and Objectivity

Scientific knowledge is difficult to describe completely. Science contains both an objective component, based strictly on rational facts and observations, as well as a subjective one, in which personal beliefs, values, intuition, judgment, creativity, opportunity, and psychology are all important (Chen, Development of an instrument to assess views on nature of science and attitudes toward teaching science, 2006). Though students do not often dispute that the empirical component of science is important, they often fail to understand the role of the subjective (McComas, 1998).

As the question on the VOSE that determined parsimony as it relates to subjectivity and objectivity was the same as the one used to examine student opinions on the effect of parsimony on the validation of scientific knowledge, the difference in this area is identical: Treatment students were significantly less likely to believe that parsimony is a crucial part of scientific knowledge [$F(1, 107) = 3.3565$, $p = 0.0698$]. Cognitive development did not have a significant effect on student responses. Paradigm, though it was determined using a different set of questions for subjectivity and objectivity, displayed a statistically significant difference as did its counterpart in validation of scientific knowledge. Treatment students were significantly more likely to believe that scientific knowledge is not influenced by the current paradigm than were Control students [$F(1, 108) = 10.2252$, $p = 0.0018$]. TOSR score was not a significant factor for determining a student’s opinion of paradigm or parsimony as they relate to objectivity and subjectivity in science.

Though the difference between the two was significant, neither Control nor Treatment had a very strong opinion on paradigm, with average student responses being close to neutral. On average, Control students believed that paradigm was a factor in scientific knowledge where Treatment students felt that it was not. Much the same explanation of this phenomenon as was discussed in the validation of scientific knowledge is relevant here. The key difference appears to specifically be the manner in which students were learning about the nature of science. Treatment students, who were directly instructed on the Learning Cycle and the nature of science by their instructors, never utilized the paradigm in the formation of scientific knowledge, so they believed it was not a crucial component. Control students, on the other hand, derived knowledge about the nature of science strictly through experience without direct instruction. As a result, they were less likely to exclude it as a possible component of scientific knowledge. The direct instruction seems to be the key here; Treatment students, who were cognizant of their instruction, believed that they were being instructed on every aspect of science, which was not the case. As a result, they were left with greater misconceptions about the role of paradigm in scientific knowledge than were Control students.

Personal Factors

Personal factors, or characteristics like age, gender, and race, color a scientist's views on science, despite efforts to the contrary (Chen, Development of an instrument to assess views on nature of science and attitudes toward teaching science, 2006). Though neither treatment [$F(1, 107) = 6.172$, $p = 0.4339$], TOSR score [$F(1, 107) = 0.2820$, $p =$

0.5966], nor an interactive effect between these two factors [F (1, 107) = 0.6843, p = 0.4100] proved to significantly alter student perception of the importance of personal factors, overall most students believe that personal factors are influential in science.

However, cognitive development is a deciding factor in student perception of how instructors should approach the role of personal factors in the classroom. Students with high TOSR scores are more likely than those with low TOSR scores to believe that instructors should teach the role of personal factors in science [F (1, 106) = 5.6413, p = 0.0194].

Most students, regardless of treatment and TOSR score, believed that personal factors were important in science. However, only those students with high TOSR scores are likely to believe that this role should be taught. An examination of the different learning styles of concrete operational and formal operational students offers a likely explanation for this trend. While formal operational students will have a more complete understanding of formal concept, concrete operational students, when faced with formal operational material, often utilize rote learning (Wankat & Oreovicz, 1992). Formal operational students will see new information as fitting into an existing structure, and believe that it should be taught. Concrete operational students, who possess less understanding of the subject matter, believe that the importance of personal factors is another set of facts to memorize, and are less likely to believe that they should be taught.

Experimental Facts

One of the most important facets of scientific knowledge is its basis on scientific facts. For the most part, students in this study displayed some amount of agreement with this idea. However, treatment and TOSR score had a combinatorial effect on students' perceptions of the importance of facts in scientific observations [$F(1, 108) = 3.6283$, $p = 0.0596$]. However, post-hoc analysis did not show a significant difference between groups of students. This may be an indication that even though most students agree that experimental facts are a component of scientific facts, there is still a wide degree of variation with responses.

That most students realized the importance of scientific facts is not surprising. Both Treatment and Control students directly utilized experimental data in the Concept Invention phase for nearly every experiment during the semester to lead to the creation of a scientific principle. Students are also evidently influenced by TOSR score and Treatment in formulating these opinions, though the reasoning for this is difficult to deduce given the wide variation in responses.

Personal Beliefs

TOSR score appears to have a direct correlation with student perception of the role that personal beliefs have in science. Students with high TOSR scores are significantly less likely than those with low scores to believe that scientists are not influenced by their personal beliefs when conducting research [$F(1, 107) = 3.4518$, $p = 0.0660$].

Though in theory scientists try to avoid being influenced by their personal opinions, philosophical, thematic, religious, cultural, political, and economic beliefs can color the ways that scientists conduct research (National Academy of Sciences; National Academy of Engineering; Institute of Medicine, 1995). All but the most concrete operational of students, on average, responded with some degree of agreement that scientists are influenced by their personal beliefs. As treatment did not have a significant effect on the influence of personal beliefs, just like the relationship between theories and laws, it is difficult to attribute this difference to student experiences in general chemistry alone. Formal operational and concrete operational students are likely to have had different experiences in previous science classes based on differing levels of understanding of the material, which could be responsible for these differing interpretations of the role of personal beliefs in science.

The Scientific Method

The belief that science follows a strict set of rules (a universal scientific method) is one of the most widespread misconceptions in science education (McComas, 1998). Rather, science is a malleable process that does not follow a strict set of guidelines.

Students did not report significant differences in their belief in a universal scientific method from treatment [F (1, 108) = 1.2754, $p = 0.2614$], TOSR score [F (1, 108) = 0.1195, $p = 0.7303$], or an interactive effect of these two factors [F (1, 107) = 0.0479, $p = 0.8271$]. Overall, most students believe in the existence of a universal scientific method.

Since students possess widespread misconceptions about the existence of the scientific method, it is not surprising that most agree that instructors should teach the universal scientific method. The interaction between treatment and TOSR score appears to have a significant effect on student opinions on whether or not scientists should teach the universal scientific method [$F(1, 107) = 2.8744$, $p = 0.0930$]. Post-hoc analysis does not show significant differences between groups of students, however. As is the case with previous analyses, this may be the result of large sample variance. Similarly to student responses for the belief that scientific knowledge is discovered, the high average scores of this item relative to the maximum score may also play a role in the lack of differences observed through post-hoc analysis.

Overall, both Treatment and Control students, like most students in science classes, showed widespread misconceptions about importance (or lack thereof) of the scientific method and its role in scientific discovery.

VOSE Results Summary

Given the large amount of information discussed in the VOSE it is helpful to examine the differences uncovered holistically. The following sections analyze differences uncovered by the VOSE by areas of effect.

Treatment

Differences seen between students based strictly on treatment are summarized in Table 5.1.

Table 5.1: Summary of VOSE Differences due to Treatment

- Treatment students are less likely than Control students to think that scientific laws are more certain than theories [F (1, 107) = 3.0201, p = 0.0852].
- Treatment students are less likely than Control students to believe that scientific knowledge could be validated by the existing paradigm [F (1, 108) = 11.9718, p = 0.0008].
- Treatment students are less likely than Control students to believe that the existing paradigm could influence current scientific research [F (1, 108) = 10.2252, p = 0.0018].
- Treatment students were also less likely than Control students to believe that parsimony could be a reason for the validation of scientific knowledge [F (1, 107) = 3.3565, p = 0.0698].

Treatment appears to have varied effects on students' perception of the nature of science. On one hand, Treatment students possess fewer misconceptions than Control students regarding scientific theories and laws than do Control students. However, they also show an increased tendency for misconceptions regarding the role of paradigm and parsimony in scientific knowledge.

Given the nature of the treatment in this study, the tendency of Treatment students to have misconceptions regarding parsimony and paradigm is not surprising. In these instances, Treatment students tended to have a more idealized opinion of scientific knowledge than did Control students. Science strives to maintain objectivity and minimize external influences and personal beliefs (Datson & Galison, 1992). However, in actuality, science is a human-driven process, and is unavoidably subject to these influences (Chen, Development of an instrument to assess views on nature of science and attitudes toward teaching science, 2006).

In this study, students experienced the process of science first-hand, with some instruction detailing science as a process. However, the class structure did not specifically outline the effects of paradigm and parsimony, and neither factor was used when students underwent concept invention in recitation. In a sense, science in the context of this study was performed in a sort of humanistic vacuum, where the only deciding factors were objective facts. It is only by explaining to students that they are actually experiencing science that they begin to draw on the class structure for guidance. As seen from these factors, this can have both positive and negative consequences. It is apparent from these results that though instructing students on the Learning Cycle can have powerful effects on student perception of the nature of science, care must be taken to maximize the experiments themselves. Students who understand the theoretical basis of the learning strategy are likely to develop misconceptions about the nature of science unless special care is taken to mention inaccuracies during instruction.

The effect of parsimony, paradigm, and the relationship between theories and laws showed significant differences regardless of cognitive development. As these three processes are not overly formal in nature, students showed significantly different understandings of these concepts across all levels of cognitive development.

Cognitive Development

Differences between students based strictly on cognitive development (as determined by the Test of Scientific Reasoning) are summarized in Table 5.2.

Table 5.2: Summary of VOSE Differences due to Cognitive Development

- Students with high TOSR scores favor the Revolutionary view [$F(1, 107) = 7.8209$, $p = 0.0062$] when examining the tentativeness of scientific knowledge. Students with low scores preferentially favor the Cumulative view [$F(1, 107) = 9.3480$, $p = 0.0028$].
- Students with high TOSR scores are more likely than those with low scores to think that scientific laws are more certain than theories [$F(1, 107) = 5.8424$, $p = 0.0174$].
- Students with high TOSR scores are more likely to believe that scientists are influenced by their personal beliefs than those with low TOSR scores [$F(1, 107) = 3.4518$, $p = 0.0660$].
- Students with high TOSR scores are more likely to believe that instructors should teach the tentativeness of knowledge than those with low TOSR scores [$F(1, 108) = 3.9346$, $p = 0.0499$]. They are also less likely to believe that instructors should avoid teaching the tentativeness of scientific knowledge [$F(1, 107) = 6.5969$, $p = 0.0116$].
- Students with high TOSR scores are more likely to believe that instructors should teach the relationship between theories and laws than those with low TOSR scores [$F(1, 107) = 4.2529$, $p = 0.0417$].
- Students with high TOSR scores are more likely to believe that instructors should teach the importance of personal factors to students than those with low TOSR scores [$F(1, 106) = 5.6413$, $p = 0.0194$]. They are also less likely to believe that instructors should avoid teaching the importance of personal factors than those with low TOSR scores [$F(1, 107) = 4.2535$, $p = 0.0417$].

Cognitive development significantly affects student interpretation of many aspects of the nature of science, regardless of treatment. Formal operational cognitive development appears to be responsible for both increased understanding of and increased misconceptions about the nature of science. Students with high TOSR scores are more likely to believe that scientists are influenced by their personal beliefs than those with low TOSR scores, which is a more accurate interpretation of the nature of science. On the other hand, formal operational students are more likely to have misconceptions about the relationship between theories and laws, the role of personal beliefs in science, and the strictness of science as a process. And though students with high TOSR scores do not always share common opinions about the nature of science, they are more likely to believe that aspects of the nature of science should be taught in a science classroom. Students with high TOSR scores preferentially supported the revolutionary theory of scientific knowledge compared to a cumulative approach by students with low TOSR scores, but as this area is the subject of debate by scientists, neither view can be considered a misconception.

Specifically attributing any of these differences directly towards instruction with the Learning Cycle is difficult, as students with formal operational thinking ability are likely to have significantly different academic histories than are concrete operational students. However, it can be concluded that these differences were not significantly affected by instruction of the Learning Cycle, as with the exception of the relationship between theories and laws, these scores did not differ significantly between Treatment and Control sections.

Overall, students with higher TOSR scores on average displayed greater misconceptions about the nature of science than did those with low scores. This is contrary to what might be expected, as the formal process by which science operates would seem to cater towards formal operational students. Some of these differences, such as the relationship between theories and laws and science following a strict methodology, are likely due to the prevalence of common misconceptions that formal operational students are more likely to have been exposed to.

Though it is impossible to completely rule out the effect of previous knowledge, some differences can be explained from increased understanding of the Learning Cycle. The tendency of students with high TOSR scores to ascribe to the Revolutionary view of science, and the belief that scientists are influenced by their personal beliefs, can easily be explained by examining aspects of the Learning Cycle itself. As these changes were observed independently of treatment, students are reaching these conclusions without instruction. As students are left to infer these aspects without direct instruction, not surprisingly, formal operational students appear to be more influenced without instruction than concrete operational students.

Interaction

A variety of factors about the nature of science are due to an interactive effect between a student's cognitive development and treatment. These are summarized in Table 5.3.

Table 5.3: Summary of VOSE Differences due to Treatment and TOSR Score Interaction

- Control students with high TOSR scores are more likely than Control students with low TOSR scores and Treatment students with high TOSR scores to believe that observations should be theory-laden [F (1, 108) = 3.0098, p = 0.0857].

- The interaction of treatment and TOSR score significantly affects student opinion on whether scientific knowledge can be discovered only [F (1, 108) = 3.2930, p = 0.0725]. There is no significant difference between groups of students.

- The interaction of treatment and TOSR score significantly affects student opinion on whether scientific knowledge can be both discovered or invented [F (1, 108) = 3.3886, p = 0.0685]. There is no significant difference between groups of students.

- The interaction between treatment and TOSR score has a significant effect on student opinion on the importance of experimental facts in scientific knowledge [F (1, 108) = 3.6283, p = 0.0596]. There is no significant difference between groups of students.

- The interaction between treatment and TOSR score has a significant effect on student opinion on the whether or not instructors should teach the universal scientific method [F (1, 107) = 2.8744, p = 0.0930]. There is no significant difference between groups of students.

Analysis of the interaction effect of treatment and TOSR score is challenging for most aspects, as though a significant interaction is revealed through ANOVA analysis, post-hoc analysis does not show a significant difference between groups of students. Though it is clear that this interaction is affecting student responses for the epistemology of scientific knowledge (discovered or discovered and invented), the importance of experimental facts, and the role of universal scientific method in the classroom, the exact nature of this effect cannot be determined. It is possible that this may be due to large sample variance, or the proximity of some of these means to the maximum score for each category.

The significant difference in the theory-laden nature of observations shows that Control students with high TOSR scores are significantly less likely than Control students with low TOSR scores and Treatment students with high TOSR scores to display misconceptions about the importance of theory in scientific observations. Treatment students with high TOSR scores, it would appear, can develop misconceptions about aspects of science if discrepancies from the Learning Cycle are not specifically addressed during instruction.

Conclusions

1. Instructing students on the theoretical basis for the Learning Cycle significantly improves student performance on laboratory assignments.
2. Students are more likely to use information from the lecture portion of the class to make conclusions in lab when they are instructed on the theoretical basis of the Learning Cycle.
3. Students with predominantly formal operational thinking are significantly more likely to display higher metacognitive capabilities when they are exposed to the theoretical basis for the Learning Cycle. This instruction appears to adversely affect the metacognitive abilities of more concrete operational thinkers.
4. Instruction on the Learning Cycle increases student understanding in many areas, especially if students are formal operational. However, this instruction can significantly increase the misconceptions of concrete operational students.

5. Even minor deviations in the Learning Cycle can cause significant student misconceptions if these deviations are not directly addressed during instruction.

Suggestions for Further Research and Practice

1. Learning Cycle laboratories need to be made to better encapsulate the nature of science. Eliminating common misconceptions of students who are taught the theoretical nature of the Learning Cycle through experimental modification would make such instruction even more useful from a pedagogical viewpoint.
2. Studies are needed to directly evaluate student comprehension of the Learning Cycle in general chemistry and its relationship to student grades, metacognition, views on the nature of science, and connection between the lab and lecture sections. While this study noted major differences in the views and attitudes of Treatment and Control students, it did not examine the effect of differing levels of understanding of the Learning Cycle. Will Treatment students who better understand the Learning Cycle have different views than Treatment students than those who struggle with the concept?
3. The tendency of concrete operational students to struggle with Learning Cycle instruction is obvious from this study. Efforts should be made to teach the Learning Cycle in a more concrete manner and examine what effect this has on the understanding of both concrete and formal operational students.
4. Development of a more detailed survey on student opinions on lab and lecture is needed. Though short, survey results suggests that there is a significant difference

between Treatment and Control students that may extend beyond the questions analyzed in the context of this study.

5. Though this study successfully caused students to use information from the lecture portion in lab, the increased use of material from lab in lecture was not observed. Extending instruction of the Learning Cycle to the lecture portion could further unify both portions, and could affect student performance in the lecture portion as well as the lecture portion.

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Appendicies

Appendix A.1

Learning Cycle Evaluation Worksheet (LCEW)

Name______________________________

Experiment______________

Section #______________

Learning Cycle Evaluation Worksheet (LCEW)

1. **Exploration**. What do you think are the most important observations from the exploration portions of this lab? Explain why you think these observations are important.

2. **Concept Invention**. What was the concept that you discovered in the exploration phase? What *specific* observations support this concept?

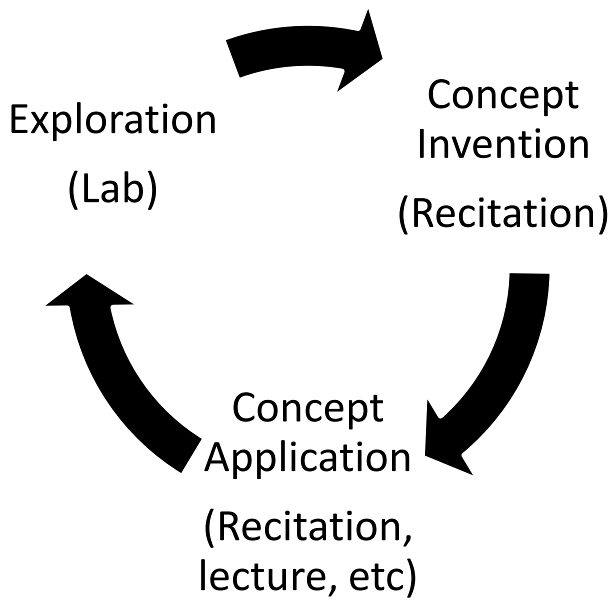
3. **Concept Application**. What are three uses of this concept in the area of chemistry that you can think of? Explain how the concept is used in your three applications. Your three uses can be things you learned about in lecture or ways you could use the concept in lab.

Appendix A.2

Learning Cycle Student Handout

The Learning Cycle

The Learning Cycle is a method of teaching science classes that is used in CHEM 1315. The Learning Cycle has been shown in research to be a beneficial way of teaching chemistry to students! We'll talk about the reasons the Learning Cycle is effective later on in the semester.



In the Exploration phase, you will experience firsthand a new idea or concept in general chemistry. This occurs in the lab.

In the Concept Invention phase, you will use your observations from lab to establish an idea or concept in general chemistry. Your TA will help you do this as a group in recitation.

In the Concept Application phase, you will take the idea you invented and apply it to other tasks. This may take the form of a worksheet in recitation, listening to your lecture instructor teach about the concept you invented, or in homework assignments you work through.

Assignment

As a group, create your own Learning Cycle for teaching students something new (it doesn't have to be related to science). Establish what the students will do in each phase of the learning cycle

Appendix A.3

Nature of Science Student Handout

Name________________________________

Section #___________

What is Science?

1. In your own words, describe what science is.

2. How is information added to the body of scientific knowledge? In other words, what process do scientists use to discover facts?

3. How stable is the body of scientific knowledge? In other words, how likely are scientific facts to change?

Name________________________________

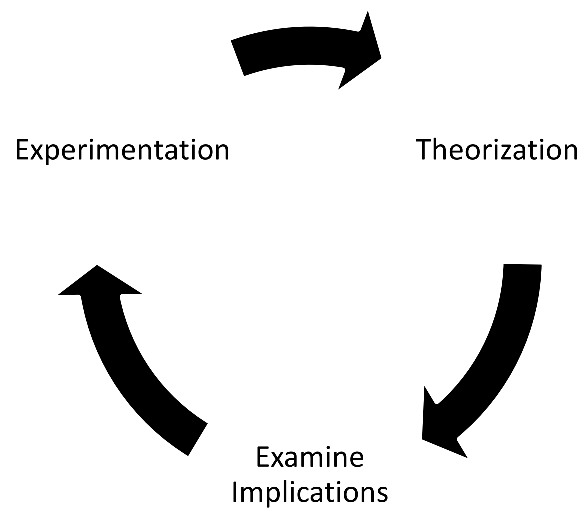
Section #___________

By now you have some familiarity with the Learning Cycle. The Learning Cycle consists of three phases (Exploration, Concept Invention, and Concept Application) and is used in CHEM 1315. What you may not be aware of is that the Learning Cycle mimics the way that scientists add to the body of scientific knowledge!

Scientists first begin by experimenting. Their research is often driven by a hypothesis about what they are researching. This is similar to the Exploration phase of the Learning Cycle.

Next, scientists then take the observations they made during experimentation and devise scientific theories that explain their observations. This is analogous to the Concept Invention phase.

Scientists then examine the implications of their new theory. This often leads to further investigation into other related aspects of the theory. This is like the Concept Application phase.



Examine your answers for the first worksheet. Answer the questions again, changing any misconceptions you might have had about the nature of science.

Appendix A.4

Learning Theory Handout

Name________________________________

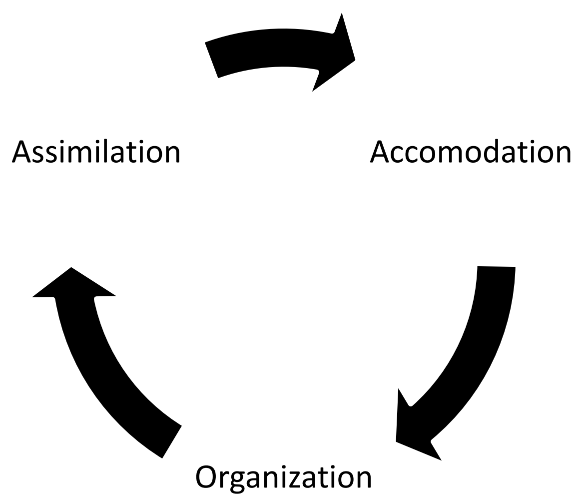
Section #___________

By now you have some familiarity with the Learning Cycle. The Learning Cycle consists of three phases (Exploration, Concept Invention, and Concept Application) and is used in CHEM 1315. What you may not be aware of is that the Learning Cycle mimics the way that the mind processes new information! It follows a model called the mental functioning model, which is a cycle developed by the Swiss psychologist Jean Piaget.

Assimilation is the process by which the brain takes in new information. This information could come from any source, including instruction or direct observation. This is similar to the Exploration phase of the learning cycle, where students are exposed to new information for the first time.

After assimilating new information, the mind must make sense of this new information, especially if it contradicts what the mind already knows. This process is called accommodation. Accommodation is similar to the Concept Invention phase, where observations from lab are explained in recitation.

The final phase, organization, is where the mind fits the newly accommodated information into the other things it knows. If this new information contradicts something else the mind knows, it begins another cycle of assimilation, accommodation, and organization! This is analogous to the Concept Application phase of the Learning Cycle, where the idea discussed in the Concept Invention phase is applied to other areas.



Assignment:

Starting with a misconception, explain what happens during each of these phases in the brain when someone is exposed to new information. Be sure to address what the misconception is, how the new information contradicts it, and what other kinds of ideas it will affect in the organization phase.

Appendix A.5

Learning Cycle Review Handout

Name________________________________

Section #___________

Learning Cycle Review

This semester you have experienced a Learning Cycle class first hand in CHEM 1315. You have also examined the reasons the Learning Cycle is used in science courses through assignments in recitation and in the Learning Cycle Evaluation Worksheet (LCEW). The Learning Cycle is based on both how science operates, and how people think. This makes it an effective tool in teaching! The comparisons between the Learning Cycle and these methods are summarized on the diagram on the last page of this packet. Use what you have learned to answer the following questions about the Learning Cycle.

1. For the following terms, match up the description on the left with the phase on the right.

____The mind process new information, even if it contradicts what it already knows

____A scientist's hypothesis guides his or her work in this phase

____The TA helps students make sense of information in this phase

____The theoretical explanation for observations is examined in a broader sense, often starting new research

___The mind organizes information in the context of other things it knows

____Learning cycle phase that occurs primarily in the lab

____A scientist uses data from experiments to explain what was seen

____Reading the textbook and answering worksheet questions occur in this phase.

____The mind takes in new information

A. Exploration

B. Concept Invention

C. Concept Application

D. Experimentation

E. Theorization

F. Examine Implications

G. Assimilation

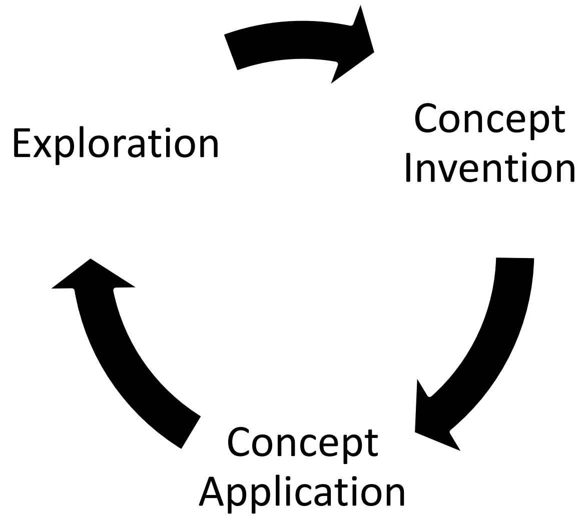
H. Accommodation

I. Organization

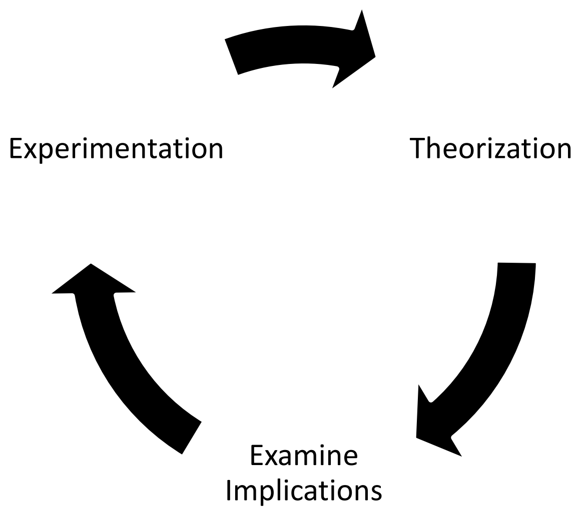
2. Relate how the mind process information (Piaget's mental functioning model) to the process by which science operates. Explain how the phases in one phase are related to the phases in the other cycle.

3. In the context of learning chemistry, which do you think is more important: understanding how science works, or understanding the process by which people think? Explain your answer.

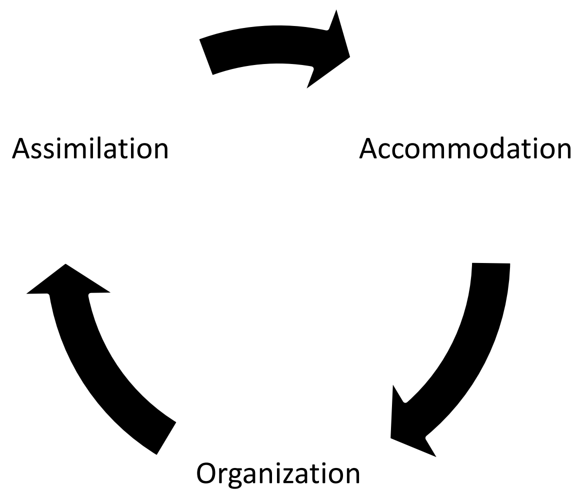
The Learning Cycle



How Science Works



How People Think



Appendix B

Lab-Lecture Survey (LLS)

Lab Lecture Survey (LLS)

Analyze the following statements and report how much you agree with them.

- Strongly Disagree
- Disagree
- Agree nor Disagree
- Agree
- Strongly Agree

1. The lab component helped me to understand chemistry concepts.
2. I used things that I learned in lab to help me understand concepts in lecture.
3. I used things that I learned in lecture to help me understand things I did in lab.
4. It is difficult to understand chemistry concepts without going to lab.
5. If it wouldn't affect my grade, I would choose to take general chemistry without taking the lab component.
6. If concepts are not discussed in lab I don't understand them as well.
7. I view the lab portion as separate from the lecture portion.
8. The lecture portion of general chemistry is more helpful than the lab portion.

Appendix C

Complete Data for All Subjects

Number	Section	TOSR 1	TOSR 2	TOSR 3	TOSR 4	TOSR 5	TOSR 6	TOSR 7	TOSR 8
1	T	2	4	2	2	2	3	4	1
2	T	2	4	1	5	2	3	4	1
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46	T	2	4	1	5	2	3	4	1
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Number	Section	TOSR 1	TOSR 2	TOSR 3	TOSR 4	TOSR 5	TOSR 6	TOSR 7	TOSR 8
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Number	Section	TOSR 1	TOSR 2	TOSR 3	TOSR 4	TOSR 5	TOSR 6	TOSR 7	TOSR 8
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Number	TOSR 9	TOSR 10	TOSR 11	TOSR 12	TOSR 13	TOSR 14	TOSR 15	TOSR 16	TOSR 17
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Number	TOSR 9	TOSR 10	TOSR 11	TOSR 12	TOSR 13	TOSR 14	TOSR 15	TOSR 16	TOSR 17
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Number	TOSR 9	TOSR 10	TOSR 11	TOSR 12	TOSR 13	TOSR 14	TOSR 15	TOSR 16	TOSR 17
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108	3	2	1	4	1	3	2	4	4

Number	TOSR 18	TOSR 19	TOSR 20	TOSR 21	TOSR 22	TOSR 23	TOSR 24	LLS 1	LLS 2
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Number	TOSR 18	TOSR 19	TOSR 20	TOSR 21	TOSR 22	TOSR 23	TOSR 24	LLS 1	LLS 2
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93	5	1	4	5	4	3	3	3	2
94	5	1	4	3	2	2	1	1	1

Number	TOSR 18	TOSR 19	TOSR 20	TOSR 21	TOSR 22	TOSR 23	TOSR 24	LLS 1	LLS 2
95	5	1	4	5	2	1	2	1	1
96	5	1	4	1	2	1	2	3	4
97	5	1	4	1	1	1	2	5	5
98	5	1	4	2	1	3	1	5	5
99	5	3	1	3	2	1	1	5	5
100	5	2	1	5	2	1	2	2	1
101	5	1	4	1	2	2	2	4	4
102	5	1	4	1	1	2	3	1	1
103	5	1	2	2	1	2	3	5	5
104		1	4	4	4	2	3	2	2
105	5	1	4	1	2	2	2	4	4
106	5	1	4	5	1	1	2	3	3
107	5	1	4	1	1	3	2	4	4
108	2	3	4	2	3	1	3	4	2

Number	LLS 3	LLS 4	LLS 5	LLS 6	LLS 7	LLS 8	MCAI 1	MCAI 2	MCAI 3
1	4	2	5	1	4	5	5	4	5
2	5	4	2	2	2	5	5	5	5
3	4	3	2	3	2	2	4	3	4
4	3	3	3	3	4	2	4	3	4
5	5	3	3	4	3	5	4	4	4
6	2	2	4	1	5	3	2	2	2
7	5	1	4	2	3	5	5	5	5
8	4	2	2	5	4	3	5	4	4
9	4	5	2	5	3	2	4	3	4
10	2	1	5	1	4	5	5	5	5
11	4	2	4	2	4	4	4	4	4
12	4	3	2	3	2	3	4	4	4
13	5	3	2	2	4	4	4	4	4
14	2	2	2	3	4	1	3	4	4
15	4	3	1	3	2	4	4	4	4
16	4	3	4	3	4	4	5	5	3
17	4	1	5	2	4	5	4	3	4
18	4	3	3	3	4	4	4	3	5
19	3	4	3	4	3	2	4	4	5
20	5	2	5	3	4	5	5	5	5
21	4	3	2	4		3	5	4	4
22	4	3	4	4	4	3	4	5	4
23	4	3	3	2	4	3	4	4	4
24	5	3	2	3	2	3	5	4	4
25	4	2	2	4	2	3	4	4	4
26	5	4	1	5	3	2	5	4	5
27	4	2	4	4	5	5	5	4	4
28	4	4	3	2	2	3	5	4	5
29	5	2	4	2	3	5	4	5	5
30	4	4	1	4	5	2	4	4	4
31	3	2	4	4	4	5	5	5	4
32	4	2	4	3	4	5	5	4	3
33	5	4	2	4	4	1	4	4	4
34	4	2	5	4	4	4	4	5	4
35	4	3	1	3	3	2	4	3	3
36	3	5	2	5	5	1	4	3	4
37	4	3	3	4	4	3	4	3	4
38	1	2	2	2	2	2	1	1	1
39	5	1	5	1	5	5	5	5	4
40	4	4	2	4	3	2	4	4	4
41	3	1	5	1	5	5	5	5	5
42	4	2	4	4	4	4	4	4	4
43	4	1	5	4	5	4	5	4	4
44	4	5	2	4	3	3	4	3	4
45	4	3	2	2	4	3	4	5	5
46	3	2	4	4	4	3	5	5	4
47	4	1	4	2	3	5	4	4	4

Number	LLS 3	LLS 4	LLS 5	LLS 6	LLS 7	LLS 8	MCAI 1	MCAI 2	MCAI 3
48	5	3	5	2	5	5	5	4	5
49	3	2	4	2	4	4	5	5	4
50	2	3	4	3	5	1	4	4	3
51	5	3	3	4	4	4	3	4	5
52	4	3	4	3	4	5	4	3	4
53	3	4	3	3	3	3	4	4	4
54	3	2	4	3	2	3	2	4	3
55	2	4	1	4	2	1	4	3	4
56	4	2	4	2	4	5	5	4	4
57	4	3	3	4	4	4	4	5	4
58	4	3	3	4	4	4	4	5	4
59	4	2	5	1	4	5	5	4	5
60	3	2	4	1	4	3	4	4	4
61	2	5	1	4	2	3	4	3	2
62	4	3	2	3	3	4	4	4	4
63	3	1	5	3	4	4	4	3	3
64	4	3	2	4	2	3	4	3	3
65	4	4	2	4	4	2	4	4	
66	4	2	4	4	4	2	2	4	4
67	3	2	4	2	4	5	3	4	4
68	4	3	2	3	4	5	5	5	4
69	1	4	2	4	3	1	5	4	4
70	1	2	5	3	4	3	5	5	5
71	4	5	1	4	3	2	4	5	5
72		3	3	4	3	3	3	4	5
73	3	4	2	4	5	1	4	3	4
74	1	2	4	2	4	3	4	4	4
75	5	5	1	4	3	2	5	5	5
76	2	4	4	2	4	2	4	5	4
77	3	1	4	2	4	4	5	4	5
78	4	2	5	1	4	4	5	5	5
79	4	2	4	3	5	3	4	2	4
80	2	5	2	3	4	1	5	5	4
81	5	3	3	2	3	4	5	4	4
82	4	3	3	3	4	4	4	4	4
83	4	3	4	2	4	5	5	4	4
84	4	2	4	3	2	3	1	2	2
85	3	1	4	2	4	4	5	4	4
86	4	3	3	4	3	2	5	5	4
87	4	2	2	4	5	2	4	5	4
88	3	5	4	5	2	3	4	4	3
89	4	3	2	5	3	3	4	5	2
90	4	5	3	5	5	3	4	2	5
91	4	2	5	2	5	5	5	4	3
92	4	2	4	4	4	5	4	4	5
93	4	3	5	2	5	4	4	5	4
94	5	1	5	1	5	5	5	4	5

Number	LLS 3	LLS 4	LLS 5	LLS 6	LLS 7	LLS 8	MCAI 1	MCAI 2	MCAI 3
95	4	1	5	1	5	4	3	5	4
96	4	2	3	4	4	4	1	1	1
97	3	4	1	4	2	1	4	4	4
98	2	2	2	4	4	1	4	4	2
99	5	4	2	3	4	3	5	5	5
100	3	2	5	2	5	5	5	5	5
101	4	3	3	2	4	4	5	4	5
102	1	1	5	1	3	5	5	2	5
103	5	2	2	5	4	2	5	4	5
104	3	2	4	2	4	5	4	3	4
105	2	2	2	5	4	2	4	4	4
106	4	2	5	2	5	5	4	4	4
107	4	2	2	4	2	3	4	4	4
108	2	2	2	2	4	5	4	4	4

Number	MCAI 4	MCAI 5	MCAI 6	MCAI 7	MCAI 8	MCAI 9	MCAI 10	MCAI 11	MCAI 12
1	5	5	5	5	5	5	5	3	5
2	5	5	5	5	5	5	5	5	5
3	4	4	3	2	2	4	4	2	4
4	4	4	3	4	4	2	2	2	4
5	4	5	3	4	3	4	5	4	4
6	4	4	4	4	2	2	2	2	4
7	5	5	5	5	5	5	5	5	5
8	5	4	4	3	5	5	5	2	4
9	4	4	4	4	4	5	3	4	3
10	4	4	4	4	4	4	3	1	2
11	3	2	4	4	4	3	4	2	3
12	3	4	4	4	4		3	2	4
13	4	4	4	4	5	4	4	3	4
14	4	3	4	2	2	2	5	4	3
15	5	4	4	3	3	4	5	2	3
16	2	4	3	4	4	3	4	2	2
17	4	4	3	2	5	4	3	2	2
18	4	4	3	2	5	4	3	1	4
19	4	3	2	4	4	5	2	2	2
20	4	5	5	3	2	4	4	2	4
21	4	4	4	5	4	4	4	4	4
22	3	4	4	2	3	4	5	2	2
23	4	3	3	4	4	4	5	3	2
24	4	4	4	3	4	4	3	4	4
25	4	4	4	2	4	4	4	2	3
26	4	3	4	4	5	5	3	2	4
27	5	3	4	3	5	5	5	3	4
28	5	4	2	4	4	2	2	2	2
29	5	3	5	4	5	5	5	4	5
30	5	5	2	4	4	4	4	3	4
31	5	3	5	2	5	4	2	2	5
32	4	2	4	4	4	4	3	4	4
33	4	5	4	3	4	4	3	4	4
34	4	4	4	2	4	4	2	2	2
35	4	4	4	4	4	3	3	2	4
36	5	3	4	5	4	4	4	3	3
37	3	3	3	3	4	3	4	2	2
38	2	1	1	1	4	4	4	4	4
39	5	5	5	5	4	4	5	2	5
40	4	4	4	4	4	4	4	4	4
41	5	5	5	3	5	5	5	1	4
42	4	4	4	4	4	4	4	4	4
43	5	4	3	2	5	4	3	3	2
44	4	4	4	4	4	4	4	3	4
45	4	5	4	4	4	5	5	4	3
46	5	5	5	4	5	4	5	4	4
47	3	4	4	3	4	2	2	2	4

Number	MCAI 4	MCAI 5	MCAI 6	MCAI 7	MCAI 8	MCAI 9	MCAI 10	MCAI 11	MCAI 12
48	4	4	5	5	3	2	2	2	3
49	4	4	4	4	4	4	4	4	4
50	2	4	2	3	2	4	3	3	2
51	5	4	5	5	5	5	4	3	4
52	4	4	4	2	4	4	3	3	3
53	4	4	4	3	4	4	4	4	4
54	4	2	3	4	4	3	5	3	4
55	2	4	4	3	3	4	4	3	3
56	4	5	4	4	5	4	3	2	1
57	4	5	4	4	4	5	4	4	4
58	4	5	4	4	4	5	4	4	4
59	5	4	4	3	5	5	3	3	4
60	4	3	2	4	3	4	5	4	3
61	3	5	1	2	4	2	3	4	3
62	4	4	4	5	5	5	3	2	4
63	4	4	4	3	3	4	4	3	3
64	4	4	4	3	4	3	3	4	4
65	2	4	3	4	4	4	3	2	2
66	4	5	4	2	3	4	5	2	5
67	4	4	3	3	4	3	4	4	4
68	4	3	4	4	3	4	5	2	3
69	4	3	4	4	4	4	4	4	4
70	5	4	4	4	5	5	5	3	3
71	4	4	4	5	4	4	4	3	4
72	3	3	3	4	4	4	4	3	3
73	4	5	4	5	3	5	4	2	4
74	4	4	4	4	4	4	5	4	
75	5	4	5	5	4	4	3	3	5
76	5	4	4	2	4	4	3	2	5
77	4	5	4	3	4	4	5	2	4
78	5	5	4	5	5	4	3	3	5
79	4	4	3	4	5	3	4	4	3
80	4	5	3	4	3	3	2	2	4
81	4	3	3	4	5	4	4	3	3
82	4	3	3	4	3	4	3	3	4
83	5	3	4	5	5	5	5	3	4
84		1	3	4	4	3	2	1	3
85	5	4	5	5	4	4	3	3	4
86	4	4	4	3	4	3	3	4	4
87	5	5	5	3	4	4	5	2	4
88	3	4	3	4	3	3	3	4	3
89	2	4	3	4	3	3	4	2	3
90	4	5	5	5	3	1	1	1	3
91	4	4	5	4	4	4	4	5	4
92	4	4	3	4	4	3	4	4	3
93	2	3	3	1	5	3	3	1	2
94	5	4	4	3	5	5	4	5	4

Number	MCAI 4	MCAI 5	MCAI 6	MCAI 7	MCAI 8	MCAI 9	MCAI 10	MCAI 11	MCAI 12
95	4	2	3	3	4	4	3	4	5
96	2	2	3	1	2	3	3	2	2
97	4	4	3	2	5	4	3	1	2
98	4	4	3	3	2	4	3	5	2
99	4	4	4	4	5	5	4	3	5
100	5	5	4	4	5	5	4	1	3
101	3	4	3	4	4	3	2	2	4
102	4	4	3	2	4	2	3	3	1
103	5	4	4	5	5	4	5	2	4
104	4	3	5	4	4	4	5	2	3
105	3	4	2	4	2	4	2	2	4
106	4	4	4	3	4	4	3	2	4
107	5	5	4	4	3	4	4	2	4
108	4	4	4	4	4	4	3	4	4

Number	MCAI 13	MCAI 14	MCAI 15	MCAI 16	MCAI 17	MCAI 18	MCAI 19	MCAI 20	MCAI 21
1	5	5	5	4	4	3	5	3	2
2	5	5	5	5	5	5	5	4	2
3	4	3	2	4	2	3	2	4	2
4	4	3	4	4	4	3	4	4	3
5	5	5	4	4	4	3	4	3	2
6	5	2	3	3	4	2	2	4	3
7	5	5	5	5	5	5	5	4	1
8	2	5	4	4	4	4	4	1	1
9	4	4	4	4	4	4	5	4	3
10	4	4	4	4	4	4	4	2	2
11	4	3	2	4	4	4	4	4	3
12	4	4	4	4	3	3	4	3	3
13	4	4	4	4	5	4	4	4	4
14	4	3	4	3	4	2	3	3	3
15	4	4	4	4	4	4		2	2
16	4	2	5	4	3	2	4	5	3
17	4	3	5	3	2	2	4	2	2
18	4	4	4		3	2	3	2	3
19	4	3	5	3		4	4	4	4
20	4	4	5	3	4	3	4	1	1
21	4	4	4	4	3	4	4	3	2
22	2	2	5	4	4	3	4	2	2
23	4	4	5	3	3	4	5	4	3
24	4	4	5	4	4	3	4	3	2
25	4	4	4	4	4	3	4	2	2
26	4	4	5	4	4	3	3	3	3
27	3	5	5	5	5	4	5	3	2
28	1	2	4	1	2	3	4	1	2
29	5	5	5	4	5	4	5	3	3
30	2	3	4	3	4	3	4	2	2
31	4	5	5	4	5	3	4	3	5
32	3	2	5	4	4	4	3	2	2
33	4	4	4	4	4	4	4	2	2
34	4	4	4	4	4	4	4	2	2
35	4	4	4	2	4	3	3	3	4
36	5	3	4	4	3	4	4	5	3
37	3	3	4	4	4	3	4	2	3
38	4	4	4	4		3	3	3	3
39	5	5	5	5	5	4	4	5	1
40	4	4	4	4	4	4	4	4	3
41	5	3	5	3	4	4	5	1	2
42	4	4	4	4	4	4	4	4	4
43	4	4	5	4	4	2	4	5	2
44	4	4	4	4	4	4	4	2	2
45	4	3	4	3	4	4	4	2	5
46	4	4	5	3	4	4	4	3	4
47	4	4	3	4	4	3	4	3	2

Number	MCAI 13	MCAI 14	MCAI 15	MCAI 16	MCAI 17	MCAI 18	MCAI 19	MCAI 20	MCAI 21
48	3	5	4	2	3	3	4	5	2
49	4	4	4	4	4	4	4	4	3
50	4	3	3	2	4	2	3	4	4
51	5	4	5	4	4	4	4	2	2
52	4	4	4	4	4	4	4	3	3
53	3	4	4	4	4	4	3	4	4
54	3	2	3	3	3	2	3	4	3
55	4	3	4	2	3	2	4	2	3
56	4	4	5	4	4	3	4	4	3
57	5	4	5	4	4	4	4	3	4
58	5	4	5	4	4	4	4	3	4
59	4	5	4	4	5	4	5	2	2
60	3	4	2	3	5	2	1	3	4
61	1	4	5	3	2	4	3	2	5
62	2	4	4	4	3	2	3	2	3
63	4	3	3	3	3	3	4	4	3
64	3	3	4	3	4	4	3	3	4
65	4	3	4	3	2	2	2	4	3
66	5	5	5	5	4	5	5	2	3
67	2	3	4	4	3	4	4	4	2
68	4	4	5	3	4	3	5	2	2
69	4	4	4	4	4	4	4	4	2
70	5	3	5	4	4	3	3	2	4
71	4	4	5	5	5	4	4	2	3
72	4	4	4	3	3	3	4	3	3
73	3	3	4	3	4	4	4	3	4
74	2	2	4	4	2	2	4	4	2
75	5	5	4	4	4	2	4	5	4
76	1	4	5	5	3	2	4	1	1
77	3	4	5	5	4	4	5	2	2
78	3	4	5	3	4	4	5	3	2
79		4	5	4	4	3	3	4	4
80	4	2	3	3	4	2	2	3	3
81	4	3	5	4	5	4	4	2	2
82	3	3	4	3	3	3	3	3	4
83	4	4	4	3	3	4	4	2	2
84	5	4	2	3	2		3	4	4
85	4	4			3	4	4	3	3
86	3	4	5	4	4	3	4	3	3
87	4	2	5	4	4	4	4	5	2
88	5	4	4	3	4	4	4	5	3
89	4	3	3	2	4	4	2	4	3
90	3	4	4	1	5	5	4	4	3
91	4	4	5	4	5	5	4	4	4
92	5	4	4	5	5	5	5	2	2
93	4	3	5	5	3	3	3	1	5
94	5	4	4	3	4	4	5	3	2

Number	MCAI 13	MCAI 14	MCAI 15	MCAI 16	MCAI 17	MCAI 18	MCAI 19	MCAI 20	MCAI 21
95	4	4	4	3	3	3	2	3	3
96	3	3	3	3	2	2	3	5	4
97	4	5	5	4	4	4	3	3	4
98	4	4	4	3	3	2	2	4	1
99	5	4	5	5	5	4	4	4	2
100	5	4	4	3	4	4	4	2	1
101	4	2	4	4	2	3	4	2	2
102	3	3	4	5	5	3	4	2	3
103	5	5	5	5	5	5	5	2	3
104	2	2	5	4	3	3	3	3	3
105	4	4	2	4	4	2	3	5	2
106	5	3	4	4	4	4	4	2	2
107	4	4	4	4	4	4	4	3	2
108	4	4	4	4	4	4	4	4	4

Number	MCAI 22	MCAI 23	MCAI 24	MCAI 25	MCAI 26	MCAI 27	VOSE 1A	VOSE 1B	VOSE 1C
1	2	1	1	1	2	1	5	4	1
2	2	2	2	2	2	2	5	5	4
3	4	4	4	2	4	4	4	4	2
4	4	4	4	3	2	3	4	4	4
5	3	2	1	2	2	1	4	4	3
6	2	3	1	2	4	2	1	1	2
7	2	1	1	1	2	1	4	4	1
8	3	2	1	2	1	3	1	3	2
9	3	3	2	3	3	4	3	4	2
10	2	1	1	1	1	2	4	3	2
11	3	2	4	2	4	4	4	4	2
12	3	2	2	2	2	3	3	3	3
13	4	2	1	2	2	2	3	3	2
14	4	1	3	4	4	4	3	3	2
15	2	1	2	2	1	3	2	2	4
16	4	2	5	2	2	4	4	5	2
17	2	1	1	2	2	4	4	2	3
18	4	3	2	2	3	4	2	4	3
19	2	4	3	2	4	4	3	4	4
20	4	2	2	3	2	2	2	2	4
21	4	2	2	2	2	2	2	2	4
22	2	2	1	1	1	4	4	4	2
23	5	5	3	4	3	4	4	4	4
24	2	3	2	3	4	3	3	4	4
25	3	2	2	2	2	4	2	2	2
26	3	2	2	1	2	2	2	2	2
27	4	1	1	1	2	3	4	2	4
28	3	2	2	1	2	1	4	3	4
29	3	1	2	1	2	2	4	3	3
30	5	2	2	2	2	5	2	2	2
31	5	2	1	2	2	5	3	4	2
32	4	2	1	2	2	4	2	2	4
33	2	2	2	2	2	2	2	2	4
34	2	2	2	2	4	2	2	4	2
35	4	2	4	2	3	4	4	4	3
36	5	3	5	5	5	3	4	4	3
37	3	3	1	4	2	3	2	3	2
38	4	3	4	3	3	3	2	1	2
39	1	1	4	3	4	1	1	1	1
40	3	2	4	2	4	4	2	4	3
41	1	3	1	1	1	1	5	5	3
42	4	2	2	2	2	2	2	4	2
43	3	2	2	2	3	4	4	2	4
44	2	2	2	2	2	2	4	4	2
45	3	2	2	2	2	4	4	4	2
46	3	1	1	1	1	1	2	3	4
47	3	2	1	2	2	4	1	3	1

Number	MCAI 22	MCAI 23	MCAI 24	MCAI 25	MCAI 26	MCAI 27	VOSE 1A	VOSE 1B	VOSE 1C
48	5	3	1	3	1	5	2	2	3
49	3	2	2	2	2	2	3	4	3
50	3	4	3	2	4	4	3	4	3
51	2	1	1	1	2	2	2	3	4
52	3	2	2	2	3	3	2	4	4
53	3	4	4	4	4	4	3	3	3
54	4	2	3	4	4	3	2	3	3
55	2	1	3	2	3	3	4	2	4
56	3	1	1	2	2	1	1	2	2
57	2	1	2	2	3	3	2	3	4
58	2	1	2	2	3	3	2	3	4
59	2	2	2	1	1	3	3	4	4
60	3	3	4	2	4	4	3	4	4
61	1	2		4	3	5	4	3	3
62	3	2	3	2	3	4	4	4	2
63	4	3	2	3	3	2	3	3	4
64	4	2	2	2	2	2	4	2	4
65	3	2	4	2	3	4	4	3	2
66	2	1	1	3	1	4	1	2	4
67	3	2	2	3	3	2	4	3	4
68	1	1	1	1	1	3	2	2	4
69	3	2	3	1	1	1	2	2	3
70	3	1	1	1	1	1	3	2	3
71	4	2	2	4	2	1	4	4	4
72	4	2	2	1	1	4	3	2	2
73	3	2	2	3	3	4	2	2	2
74	2	2	4	2	4	4	3	2	4
75	4	2	3	2	3	4	2	3	2
76	2	1	1	2	1	1	4	2	4
77	2	2	1	3	1	3	4	4	3
78	3	2	3	4	3	4	1	4	3
79	5	4	3	4	4	4	3	4	4
80	4	4	2	3	4	4	3	4	4
81	2	1	2	1	2	2	3	4	4
82	4	2	3	3	3	4	3	4	3
83	3	1	1	1	1	1	4	4	2
84	4	2	5	3	2	3	2	4	3
85	4	4	3	4	4	3	2	2	4
86	4	2	2	3	4	2	2	2	4
87	2	1	2	2	4	4	4	2	2
88	3	3	4	4	5	5	1	2	3
89	3	2	4	3	5	3	2	4	5
90	2	3	2	5	5	5	2	4	4
91	4	4	5	5	5	4	2	2	5
92	4	2	2	2	3	4	2	4	4
93	4	4	3	5	1	3	3	2	5
94	4	2	2	1	1	3	4	4	5

Number	MCAI 22	MCAI 23	MCAI 24	MCAI 25	MCAI 26	MCAI 27	VOSE 1A	VOSE 1B	VOSE 1C
95	4	3	3	4	3	3	2	3	4
96		3	4	4	4	2	4	4	3
97	1	2	2	2	2	3	1	4	4
98	1	1	1	4	4	4	1	2	4
99	3	2	1	1	1	4	3	4	5
100	2	2	1	2	3	1	5	4	2
101	4	2	2	2	2	4	3	4	2
102	4	4	2	1	2	3	3	4	4
103	1	3	1	1	1	5	3	4	4
104	3	1	1	1	3	3	5	4	3
105	4	2	2	2	4	4	2	4	4
106	4	3	3	3	2	5	1	2	4
107	3	2	2	2	2	2	2	2	4
108	4	4	4	4	4	4	4	4	4

Number	VOSE 1D	VOSE 1E	VOSE 1F	VOSE 1G	VOSE 1H	VOSE 2A	VOSE 2B	VOSE 2C	VOSE 2D
1	1	4	1	4	1	1	2	5	5
2	2	2	2	2	2	5	5	2	2
3	2	2	2	2	2	2	2	4	4
4	2	4	4	2	1	4	4	3	2
5	2	3	3	2	3	4	3	4	4
6	2	2	2	2	4	4	4	2	2
7	1	1	3	2	1	4	4	2	2
8	2	1	2	2	1	1	1	1	1
9	2	2	2	2	5	4	2	4	3
10	2	2	2	1	2	4	4	2	2
11	2	4	2	2	2	4	4	2	2
12	3	3	3	3	3	3	3	3	3
13	3	2	2	1	3	2	3	5	4
14	2	3	3	2	3	3	4	3	3
15	3	4	2	2	2	5	4	2	2
16	1	2	2	1	4	5	2	1	3
17	1	4	2	1	2	5	2	4	4
18	4	3	4	2	2	4	3	3	3
19	2		3	4	2	4	4	3	2
20		4	4	4	3	5	5	4	4
21	2	4	3	3	2	4	4	3	4
22	2	2	2	2	4	4	3	4	4
23	3	3	3	3	3	3	3	3	5
24	3	3	2	1	2	2	2	4	5
25	2	2	2	2	4	4	2	2	2
26	2	3	3	4	4	4	4	2	2
27	1	4	3	2	2	5	2	4	3
28	3	2	3	3	2	2	3	5	3
29	2	2	2	1	2	4	4	4	3
30	2		4	3	4	3	3	4	4
31	2	3	2	3	4	4	3	4	4
32	1	2	3	4	5	4	4	3	4
33	2	4	4	2	3	4	4	2	3
34	2	4	2	1	4	4	4	2	2
35	2	4	3	2	3	4	3	4	4
36	2	4	3	2	5	3	3	4	4
37	2	4	2	2	3	2	2	4	3
38	1	2	2	2	2	3	4	5	4
39	1	5	4	1	3	2	2	5	5
40	2	3	2	2	4	2	2	4	4
41	1	1	1	1	1	4	4	3	3
42	2	3	4	1	4	4	4	4	4
43	1	3	2	3	2	4	4	2	2
44	2	2	2	2	2	2	2	5	5
45	2	4	2	4	2	4	4	2	2
46	2	3	2	3	4	4	4	2	4
47	1	2	1	2	4	4	3	4	4

Number	VOSE 1D	VOSE 1E	VOSE 1F	VOSE 1G	VOSE 1H	VOSE 2A	VOSE 2B	VOSE 2C	VOSE 2D
48	1	3	2	4	4	3	2	3	4
49	3	3	3	3	3	4	3	3	3
50	4	3	2	4	4	3	4	4	2
51	3	4	3	4	3	3	3	4	4
52	2	3	2	2	2	4	4	2	2
53	3	3	3	3	3	2	3	2	3
54	2		3	4	3	3	4	3	4
55	3	4	4	4	1	4	4	2	2
56	1	1	1	1	4	3	1	3	4
57	3	4	2	2	2	4	4	2	3
58	3	4	2	2	2	4	4	2	3
59	2	2	2	3	1	4	4	3	3
60	2	3	4	3	4	4	2	2	4
61	2	4	1	5	3	2	4	3	2
62	4	4	2	2	2	2	2	4	4
63	4	3	3	4	4	4	4	3	2
64	2	2	2	3	2	2	2	4	4
65	2	2	2	2	3	4	3	2	3
66	1	3	1	4	4	5	4	2	2
67	1	3	2	1	2	4	2	4	4
68	2	3	2	1	1	4	3	2	4
69	3	3	3	1	5	3	3	3	3
70	1	3	3	2	4	4	3	4	3
71	2	4	3	2	4	4	4	4	4
72	2	3	2	2	3	4	4	2	4
73	4	2	4	2	2	4	4	4	4
74	1	4	2	1	1	4	4	2	2
75	2	4	3	2	4	4	4	1	2
76	2	4	4	4	1	4	4	2	2
77	3	2	3	2	2	4	4	3	3
78	1	2	3	2	1	3	3	2	4
79	3	4	2	3	4	3	4	4	2
80	2	3	4	4	2	4	4	2	2
81	1	2	3	1	1	4	3	4	3
82	2	3	2	2	2	2	2	4	3
83	1	2	2	2	2	4	4	3	3
84	3	2	3	2	4	3	4	5	3
85	4	4	4	4	3	4	4	3	2
86	2	5	4	4	4	5	5	3	2
87	1	3	2	2	4	4	4	4	2
88	2	3	3	1	1	4	4	3	3
89	2	3	4	3	2	4	4	2	3
90	3	4	1	4	1	5	4	2	3
91	4	3	4	3	4	4	4	2	2
92	2	2	4	2	1	4	4	2	3
93	5	1	1	1	3	5	3	3	5
94	2	2	3	4	5	4	3	4	5

Number	VOSE 1D	VOSE 1E	VOSE 1F	VOSE 1G	VOSE 1H	VOSE 2A	VOSE 2B	VOSE 2C	VOSE 2D
95	4	3	3	3	3	4	4	2	3
96	1	2	1	1	1	4	4	4	3
97	3	1	3	1	1	4	4	3	3
98	4	3	3	4	4	1	1	4	4
99	4	4	4	5	1	4	4	4	4
100	3	2	3	1	1	3	4	4	5
101	2	4	3	2	3	5	5	2	3
102	2	4	3	2	4	4	4	2	3
103	1	4	3	2	2	2	2	4	2
104	2	2	3	3	4	3	3	4	3
105	2	4	4	4	2	4	4	2	3
106	1	1	1	1	4	4	4	2	2
107	3	4	4	3	2	4	4	2	2
108	4	4	4	4	4	4	3	3	3

Number	VOSE 3A	VOSE 3B	VOSE 3C	VOSE 3D	VOSE 3E	VOSE 4A	VOSE 4B	VOSE 4C	VOSE 5A
1	5	5	1	1	2	2	5	5	4
2	4	4	2	2	2	5	4	4	5
3	2	2	4	4	4	4	4	4	2
4	3	2	4	3	2	3	4	4	3
5	4	3	3	3	4	4	4	3	5
6	4	2	2	4	2	4	2	4	4
7	3	3	4	2	3	3	4	4	5
8	2	2	2	2	2	2	2	2	3
9	3	3	4	3	5	4	3	4	5
10	4	4	2	2	2	4	2	4	3
11	2	2	4	4	4	2	4	4	4
12	3	3	3	3	3	4	4	4	4
13	3	3	3	3	3	5	3	4	4
14	3	4	2	3	2	4	4	3	4
15	4	4	2	2	2	3	3	4	5
16	3	4	1	5	2	2	2	4	3
17	3	4	4	3	4	5	1	3	2
18	4	4	2	3	3	2	4	4	3
19	2	4	4	3	3	3	4	3	3
20	5	4	1	3	2	4	4	4	2
21	5	4	2	3	2	5	3	2	4
22	5	2	4	2	2	2	4	4	4
23	3	3	4	3	3	4	3	4	5
24	5	4	1	1	1	4	3	5	5
25	4	2	2	2	2	2	2	4	2
26	4	3	2	2	2	3	3	4	4
27	4	4	3	2	2	4	2	3	4
28	2	2	3	3	4	4	2	3	2
29	4	4	2	2	3	4	4	5	4
30	5	5	2	3	4	4	2	4	2
31	4		2	3	1	4	4	5	5
32	3	2	5	3	4	3	3	5	5
33	3	3	4	4	4	4	4	4	5
34	4	4	2	2	2	4	4	4	4
35	4	3	4	4	3	2	3	4	4
36	4	4	3	2	3	3	3	5	4
37	3	2	4	2	3	2	4	3	4
38	3	4	4	3	3	3	4	4	3
39	5	2	1	4	4	3	4	5	1
40	2	2	4	4	4	4	4	3	4
41	4	4	2	2	2	4	4	4	4
42	4	3	2	2	2	2	3	4	4
43	4	4	2	4	2	2	4	5	4
44	5	4	2	4	4	4	4	4	2
45	2	2	4	4	4	4	4	4	4
46	4	4	2	2	2	4	2	3	3
47	4	4	2	2	2	4	4	4	5

Number	VOSE 3A	VOSE 3B	VOSE 3C	VOSE 3D	VOSE 3E	VOSE 4A	VOSE 4B	VOSE 4C	VOSE 5A
48	1	1	4	3	3	4	4	3	5
49	4	3	3	3	3	5	3	3	4
50	3	3	4	2	4	3	4	4	2
51	4	3	2	3	3	4	3	3	5
52	4	4	2	3	2	4	4	4	2
53	4	3	2	3	4	3	2	4	3
54	2	3	4	3	4	2	3	3	3
55	5	4	2	2	3	4	3	4	2
56	1	1	4	2	3	3	2	4	4
57	3	2	4	2	3	4	2	2	4
58	3	2	4	2	3	4	2	2	4
59	4	4	2	3	2	5	3	3	4
60	5	4	2	3	3	3	4	4	4
61	4	2	3	1	5				3
62	4	4	2	2	2	4	4	5	3
63	3	3	4	4	3	4	3	3	4
64	3	4	2	4	4	2	4	4	4
65	3	4	2	3	4	4	2	4	4
66	4		3	3	3	2	2	5	2
67	4	4	3	3	2	3	3	4	4
68	2	4	4	4	2	4	4	4	4
69	3	4	2	2	2	4	4	3	4
70	1	2	2	2	5	3	4	5	5
71	4	4	4	4	4	2	4	4	4
72	5	2	1	3	1	3	3	3	3
73	2	2	3	4	4	4	3	4	4
74	2	2	4	2	2	4	2	3	4
75	2	2	4	4	3	4	3	3	2
76	4	4	3	2	4	5	2	3	2
77	5	4	2	1	1	5	4	4	5
78	4	4	1	1	1	4	2	4	3
79	2	2	4	3	4	4	4	4	4
80	4	2	3	2	4	4	2	4	4
81	3	2	4	4	3	3	2	4	4
82	2	3	2	4	3	4	3	3	3
83	4	4	2	1	3	3	4	4	4
84	3	3	2	3	4	2	2	3	3
85	2	2	3	4	4	4	3	4	4
86	5	4	2	2	3	3	4	4	5
87	4	4	2	2	2	4	2	4	4
88	2	2	4	3	3	3	4	4	4
89	4	4	2	2	3	1	5	3	4
90	3	1	3	3	1	3	2	3	5
91	5	4	2	2	2	2	4	4	5
92	4	4	2	2	4	5	5	5	5
93	5	4	2	4	3	4	2	4	5
94	5	5	1	1	2	5	2	4	4

Number	VOSE 3A	VOSE 3B	VOSE 3C	VOSE 3D	VOSE 3E	VOSE 4A	VOSE 4B	VOSE 4C	VOSE 5A
95	4	5	3	3	2	3	3	3	4
96	4	4	3	3	2	3	2	3	3
97	4	4	2	2	2	4	3	4	3
98	1	1	4	4	4	4	4	1	4
99	5	5	2	1	2	4	4	3	4
100	4	4	2	5	4	4	4	4	4
101	2	2	4	3	5	5	2	3	4
102	2	1	4	4	4	5	2	3	4
103	4	4	3	2	2	4	3	5	4
104	4	4	2	2	2	4	4	4	2
105	4	4	2	2	2	4	4	4	2
106	4	4	2	2	3	5	4	4	4
107	3	4	2	2	3	3	2	4	3
108	3	3	3	3	3	3	3	3	3

Number	VOSE 5B	VOSE 5C	VOSE 5D	VOSE 5E	VOSE 5F	VOSE 6A	VOSE 6B	VOSE 6C	VOSE 6D
1	4	5	3	3	3	5	4	3	1
2	5	5	5	5	5	5	5	5	5
3	2	4	4	4	4	4	4	2	2
4	3	5	3	3	3	3	3	5	3
5	4	2	3	2	4	5	4	3	2
6	4	2	2	2	2	4	4	2	2
7	5	4	3	3	3	4	5	4	3
8	3	3	3	3	3	3	3	3	3
9	5	2	2	2	3	5	4	3	2
10	3	2	4	4	4	4	4	2	2
11	4	3	2	2	3	2	3	3	4
12	4	4	4	1	1	4	4	3	2
13	4	5	3	4	4	4	4	4	4
14	3	2	4	4	3	3	4	3	3
15	4	3	2	2	2	2	2	3	4
16	5	4	2	3	3	5	4	3	2
17	3	3	5	4	5	4	4	2	2
18	4	4	2	2	2	4	4	4	3
19	3	4	4	3	4	4	4	3	3
20	2	4	5	5	5	4	3	4	4
21	4	4	3	3	4	4	4	3	3
22	4	3	3	2	1	5	4	3	3
23	5	4	4	4	5	5	5	2	2
24	5	2	4	4	4	5	5	3	4
25	4	4	4	2	4	4	4	4	2
26	4	1	1	1	1	5	5	1	1
27	2	3	2	2	4	5	4	3	2
28	3	4	4	4	5	5	5	4	3
29	4	4	4	4	4	5	5	5	3
30	5	5	3	2	2	5	4	2	2
31	3	4	3		3	4	4	2	1
32	4	2	2	2	3	5	5	1	1
33	5	4	2	2	3	5	5	4	2
34	3	4	4	4	4	4	4	2	3
35	4	3	3	4	4	3	3	3	3
36	4	4	3	3	3	4	4	3	3
37	3	2	3	2	2	4	3	2	1
38	3	3	4	4	4	4	4	4	4
39	5	3	5	1	1	2	4	3	4
40	4	3	2	2	2	4	4	2	2
41	4	4	2	2	2	2	2	3	4
42	4	4	4	2	4	4	3	4	3
43	4	4	3	4	2	5	5	3	3
44	2	5	4	4	4	5	4	4	2
45	4	4	2	2	2	2	4	4	2
46	3	4	4	3	4	4	4	4	4
47	4	3	2	2	2	4	4	3	2

Number	VOSE 5B	VOSE 5C	VOSE 5D	VOSE 5E	VOSE 5F	VOSE 6A	VOSE 6B	VOSE 6C	VOSE 6D
48	3	2	2	2	3	3	3	2	4
49	3	3	3	3	3	4	3	3	3
50	2	3	4	4	4	4	4	3	2
51	4	4	4	3	3	4	4	3	2
52	2	4	4	4	4	4	4	4	2
53	2	4	3	4	3	3	4	3	3
54	3	4	4	3	2	3	3	4	4
55	3	3	4	4	4	3	3	3	5
56	4	4	4	4	4	4	5	2	2
57	4	4	3	3	4	4	4	4	4
58	4	4	3	3	4	4	4	4	4
59	4	4	3	2	2	5	4	4	3
60	3	4	4	3	3	4	4	2	3
61	4	2	5	2	3	2	4	1	3
62	3	4	4	4	4	2	3	4	4
63	3	2	3	3	4	4	4	3	2
64	4	4	2	4	4	4	4	4	4
65	3	4	3	3	4	4	3	3	2
66	2	4	4	3	3	2	2		3
67	4	4	3	3	3	4	4	3	2
68	4	4	2	2	3	4	4	4	2
69	4	4	1	1	1	4	4	3	2
70	4	3	3	2	1	5	4	3	2
71	4	4	2	2	2	4	4	4	2
72	3	3	2	2	2	4	4	3	2
73	4	4	2	2	2	4	4	3	2
74	4	2	4	4	4	4	4	4	4
75	2	4	4	4	4	4	2	3	1
76	4	4	5	3	2	4	2	4	5
77	5	2	2	2	1	5	5	2	2
78	3	4	4	4	4	3	3	4	4
79	4	4	2	3	3	4	4	2	2
80	4	4	2	2	3	4	4	3	2
81	4	5	4	3	3	4	4	4	2
82	4	4	4	4	3	3	4	4	3
83	3	4	3	4	3	5	5	3	3
84	4	3	3	4	2	3	2	3	3
85	4	3	2	2	2	4	4	3	2
86	5	4	2	2	3	5	5	2	2
87	4	2	3	2	2	4	4	3	2
88	4	4	4	4	3	3	3	4	4
89	4	3	2	4	4	4	2	4	4
90	5	3	3	3	4	5	5	4	3
91	5	5	2	2	2	5	5	4	2
92	4	3	4	4	4	5	5	2	3
93	3	4	1	1	1	5	4	3	2
94	4	5	2	2	3	4	4	4	2

Number	VOSE 5B	VOSE 5C	VOSE 5D	VOSE 5E	VOSE 5F	VOSE 6A	VOSE 6B	VOSE 6C	VOSE 6D
95	3	3	2	2	3	3	4	3	3
96	3	2	4	4	4	4	3	4	4
97	4	4	4	4	4	5	4	2	4
98	4	4	4	4	4	1	2	4	3
99	4	5	4	4	4	4	4	5	4
100	4	3	2	2	1	5	4	3	1
101	4	5	3	3	4	5	5	3	1
102	3	3	2	3	4	5	4	2	2
103	4	4	5	4	4	2	2	3	4
104	3	4	4	4	4	5	4	4	4
105	2	4	4	4	4	4	4	3	4
106	4	3	2	2	2	4	4	3	2
107	2	2	4	3	4	4	3	2	3
108	3	3	3	3	3	3	3	3	3

Number	VOSE 6E	VOSE 7A	VOSE 7B	VOSE 7C	VOSE 7D	VOSE 8A	VOSE 8B	VOSE 8C	VOSE 8D
1	1	5	4	3	2	2	4	4	5
2	5	5	5	2	4	5	2	2	4
3	2	4	4	2	2	4	2	2	2
4	3		3	3	3	4	3	4	3
5	2	2	3	4	4	3	3	4	4
6	2	4	2	2	4	2	2	2	4
7	2	4	5	2	1	4	3	3	3
8	3	3	3	3	3	3	3	3	3
9	2	4	4	4	1	3	3	3	3
10	2	4	3	2	3	3	4	2	4
11	4	2	2	3	3	2	2	4	4
12	2	3	3	2	4	3	3	3	3
13	4	4	4	3	2	3	3	4	3
14	3	3	4	3	3	4	3	3	2
15	4	2	2	4	3	3	2	2	2
16	1	4	5	3	2	2	2	5	5
17	1	5	3	4	2	2	4	4	2
18	2	4	4	2	3	2	3	4	4
19	4	4	4	2	2	4	4	3	2
20	2	4	4	2	3	4	2	2	3
21	4	4	3	2	3	4	2	2	2
22	2	4	4	4	2	4	3	2	4
23	2	5	5	1	1	3	4	4	4
24	2	4	4	3	2	3	2	4	5
25	2	4	4	2	2	2	2	2	4
26	1	4	5	3	1	4	3	2	2
27	1	5	4	4	3	2	3	4	5
28	2	4	4	3	2	4	4	3	4
29	3	4	4	3	2	3	3	3	4
30	1	4	5	3	2	1	4	4	5
31	2	5	4	2	3	5	3	4	4
32	1	4	4	3	2	3	4	2	4
33	2	5	3	4	3	5	2	2	2
34	2	4	4	4	3	2	4	4	4
35	3	4	4	3	3	4	4	3	5
36	3	3	3	4	4	5	3	2	2
37	1	4	3	2	2	2	3	4	4
38	4	4	4	4	1	4	3	4	4
39	2	1	1	4	5	1	1	3	5
40	2	2	3	3	4	4	2	2	2
41	4	4	4	3	3	4	2	2	2
42	2	4	4	2	2	2	3	4	4
43	1	4	5	4	1	4	3	3	2
44	2	4	5	2	2	4	4	4	4
45	2	4	4	2	2	2	2	4	4
46	3	5	4	4	3	3	2	2	2
47	2	4	4	2	2	4	4	4	4

Number	VOSE 6E	VOSE 7A	VOSE 7B	VOSE 7C	VOSE 7D	VOSE 8A	VOSE 8B	VOSE 8C	VOSE 8D
48	4	4	3	3	3	4	3	2	2
49	3	4	3	3	3	4	3	3	3
50	2	4	4	3	3	2	4	4	4
51	3	5	4	3	3	4	3	4	2
52	2	4	4	3	2	3	4	4	4
53	4	3	2	3	4	4	2	3	3
54	3	2	3	3	2	3	4	3	4
55	5	4	4	2	2	4	3	4	4
56	1	5	4	1	1	1	1	4	4
57	3	4	4	2	3	4	3	2	2
58	3	4	4	2	3	4	3	2	2
59	3	3	3	4	4	2	3	3	4
60	3	3	2	3	3	4	3	4	3
61	5	2	4	3	2	2	4	3	2
62	2	4	4	3	3	4	2	2	2
63	2	4	3	4	2	3	4	2	3
64	2	4	4	2	2	3	4	2	4
65	2	4	4	2	2	3	4	4	4
66	2	5	5	2	2	4	2	2	2
67	2	4	4	2	3	4	4	3	4
68	2	2	2	4	4	2	2	3	4
69	2	4	4	2	2	3	3	3	3
70	1	5	4	2	2	3	3	4	3
71	2	5	5	2	2	4	2	4	4
72	2	4	4	2	2	2	4	4	4
73	2	4	4	2	2	4	2	2	2
74	1	1	2	2	4	2	2	2	4
75	1	5	4	1	2	4	2	2	3
76	5	5	5	3	2	5	1	1	4
77	2	5	5	2	2	5	5	2	2
78	2	4	3	3	2	3	3	3	3
79	4	3	3	4	4	4	4	4	3
80	2	4	4	3	2	3	4	4	4
81	1	4	4	3	2	4	4	3	3
82	4	4	4	3	4	4	3	3	2
83	2	4	4	2	1	3	3	4	3
84	4	4	2	3	2	3	2	2	4
85	2	4	4	3	2	4	4	4	3
86	1	5	4	2	2	2	3	4	4
87	2	5	4	2	2	4	2	2	4
88	4	4	4	3	3	4	3	2	3
89	2	2	2	4	4	4	2	2	2
90	4	5	5	3	3	3	5	2	4
91	2	4	4	2	2	4	4	3	3
92	2	4	5	2	1	5	4	2	4
93	1	5	5	3	3	2	4	4	4
94	3	5	5	2	2	5	2	2	2

Number	VOSE 6E	VOSE 7A	VOSE 7B	VOSE 7C	VOSE 7D	VOSE 8A	VOSE 8B	VOSE 8C	VOSE 8D
95	2	4	2	4	3	3	4	3	2
96	4	4	4	3	3	4	2	2	1
97	3	3	4	4	3	4	3	3	2
98	4	4	4	4	4	4	5	3	4
99	4	4	4	2	2	4	4	4	4
100	3	2	3	4	3	3	3	3	5
101	1	5	5	3	4	3	4	4	4
102	2	5	4	3	2	2	2	4	4
103	4	4	4	3	3	4	2	4	2
104	5	4	5	2	3	3	3	4	4
105	4	4	4	2	2	4	2	2	4
106	2	4	4	4	1	3	3	2	2
107	2	4	4	2	2	3	2	2	5
108	3	3	3	3	3	3	3	3	3

Number	VOSE 8E	VOSE 9A	VOSE 9B	VOSE 9C	VOSE 9D	VOSE 9E	VOSE 9F	VOSE 10A	VOSE 10B
1	5	5	5	2	1	1	4	4	4
2	2	2	4	5	5	5	5	5	4
3	2	4	4	3	2	3	4	4	4
4	3	4	4	3	3	3	4	4	3
5	5	4	4	3	2	3	4	5	5
6	4	4	4	2	2	2	2	4	2
7	3	5	5	3	1	4	4	4	2
8	3	3	3	3	3	3	3	3	3
9	3	4	5	4	2	4	3	4	4
10	4	2	4	4	2	4	3	4	4
11	4	4	4	3	2	2	3	4	4
12	3	4	4	4	2	2	3	4	4
13	3	5	5	2	2	2	5	4	3
14	4	4	4	4	1	3	4	4	4
15	4	3	3	4	2	2	4	4	4
16	4	4	2	3	2	4	3	5	2
17	4	5	5	1	1	1	4	5	3
18	4	4	4	3	3	3	4	4	3
19	2	4	4	4	3	3	3	4	4
20	4	4	4	4	4	5	4	4	2
21	2	3	4	4	4	3	3	3	2
22	3	5	4	2	1	2	4	4	4
23	4	5	5	2	1	2	4	5	5
24	5	4	4	2	2	3	4	5	4
25	4	2	4	4	4	4	2	4	2
26	2	4	4	2	1	3	3	4	2
27	5	3	4	5	2	4	5	4	1
28	4	5	4	3	1	2	5	5	2
29	4	4	4	3	2	3	3	3	3
30	5	4	5	2	2	2	4	4	2
31	2	5	3	4	2	2	3	5	3
32	4	4	4	3	2	3	5	4	4
33	2	4	4	4	2	2	2	4	4
34	4	4	4	3	2	2	4	4	4
35	4	5	5	3	3	4	3	3	3
36	2	5	4	3	2	3	5	5	4
37	3	3	3	3	3	3	3	3	2
38	4	3	4	4	4	4	4	4	4
39	5	5	5	1	1	5	4	5	2
40	3	4	4	3	2	2	4	4	4
41	2	4	4	3	3	2	3	4	4
42	4	4	4	4	3	4	2	4	2
43	4	4	4	3	2	5	4	4	2
44	4	4	4	4	2	2	2	4	4
45	4	4	4	2	2	2	4	4	2
46	3	3	4	4	3	4	4	4	2
47	5	4	4	3	2	4	3	4	4

Number	VOSE 8E	VOSE 9A	VOSE 9B	VOSE 9C	VOSE 9D	VOSE 9E	VOSE 9F	VOSE 10A	VOSE 10B
48	3	4	4	3	1	3	4	4	2
49	3	3	4	3	3	3	3	4	3
50	4	4	4	3	3	3	4	2	2
51	3	5	4	3	4	4	2	5	4
52	3	4	4	4	3	4	4	4	3
53	3	3	2	3	4	2	2	2	3
54	3	2	3	4	3	4	3	2	3
55	4	3	5	4	2	4	3	4	4
56	4	3	4	2	1	3	3	4	2
57	4	4	4	2	2	3	4	4	3
58	4	4	4	2	2	3	4	4	3
59	5	4	5	4	3	2	2	4	4
60	3	3	4	4	3	3	3	2	3
61	4	2	4	3	2	4	3	2	4
62	4	4	4	3	2	4	4	4	2
63	3	4	4	3	3	3	3	3	2
64	4	4	4	3	2	2	2	4	4
65	4	4	4	2	2	3	4	2	2
66	2	4	4	2	2	4	2	4	4
67	3	4	4	4	2	3	4	4	4
68	4	5	4	4	3	2	4	5	5
69	3	4	4	3	2	2	2	4	4
70	3	4	4	3	2	2	2	4	4
71	4	2	2	4	2	2	2	4	2
72	4	5	4	3	2	2	3	4	2
73	4	4	4	4	2	2	4	4	4
74	4	2	4	2	2	4	4	5	4
75	3	4	4	3	2	2	4	5	4
76	4	3	4	5	2	3	4	4	2
77	3	4	4	3	2	1	4	4	4
78	4	4	4	3	2	3	2	4	1
79	3	2	2	4	4	2	3	2	2
80	4	4	4	4	2	4	4	4	4
81	3	4	4	2	2	3	3	5	3
82	4	4	4	3	2	3	4	4	4
83	4	4	4	4	2	3	4	4	4
84	3	1	3	2	2	4	3	3	3
85	2	4	4	3	3	2	2	4	4
86	4	4	4	3	2	3	4	4	3
87	4	4	4	2	2	4	4	4	2
88	3	4	4	4	2	3	4	4	4
89	2	3	4	3	4	4	2	4	4
90	1	5	5	3	2	3	4	5	4
91	2	4	4	4	2	2	2	5	5
92	2	4	5	3	3	2	5	4	5
93	4	4	4	4	1	1	3	5	5
94	4	5	5	2	2	2	3	5	5

Number	VOSE 8E	VOSE 9A	VOSE 9B	VOSE 9C	VOSE 9D	VOSE 9E	VOSE 9F	VOSE 10A	VOSE 10B
95	3	2	3	2	3	4	3	3	2
96	3	4	4	3	4	4	3	4	3
97	4	4	4	3	2	4	4	5	4
98	4	4	2	2	4	5	5	4	4
99	2	4	4	3	3	4	4	4	4
100	5	4	4	3	1	3	1	5	4
101	5	5	4	4	1	4	5	5	5
102	4	4	4	4	3	4	4	5	5
103	4	2	2	4	4	3	4	2	2
104	4	3	5	3	3	3	4	4	3
105	4	4	4	4	2	4	4	4	2
106	2	4	4	2	1	1	4	5	2
107	4	4	4	4	2	3	2	4	2
108	3	3	3	3	3	3	3	3	3

Number	VOSE 10C	VOSE 10D	VOSE 10E	VOSE 10F	VOSE 10G	VOSE 10H	VOSE 10I	VOSE 11A	VOSE 11B
1	4	5	5	5	4	1	2	2	4
2	4	4	5	5	5	4	5	2	2
3	4	4	4	4	2	2	2	4	4
4	3	4	2	4	3	2	3	3	3
5	5	5	5	5	3	2	4	4	4
6	2	2	2	2	4	2	2	2	2
7	3	3	4	4	4	1	3	1	5
8	3	3	3	3	3	3	3	3	3
9	4	4	4	4	3	1	3	4	4
10	4	4	4	4	2	1	2	4	4
11	4	4	4	4	2	2	3	2	3
12	4	4	4	4	3	1	2	3	3
13	4	4	4	4	2	1	1	5	4
14	3	3	4	4	2	2	3	2	2
15	3	3	4	4	4	2	2	2	3
16	4	4	5	4	3	1	3	1	4
17	4	5	5	4	1	1	1	5	5
18	4	4	4	3	4	3	3	2	3
19	4	4	3	4	2	2	2	4	4
20	4	4	4	5	4	4	4	2	4
21	4	3	4	3	4	3	4	2	2
22	3	4	4	2	3	2	2	2	3
23	5	4	4	4	3	2	3	3	4
24	4	4	4	4	3	1	3	4	4
25	3	3	4	4	4	2	4	2	2
26	3	4	4	3	3	1	3	2	3
27	4	5	5	4	4	1	3	3	4
28	3	4	4	4	3	2	2	2	4
29	4	3	4	4	4	2	3	3	4
30	4	5	5	4	2	2	3	4	4
31	4	2	3	3	3	2	4	5	3
32	3	3	4	4	4	2	3	4	3
33	4	4	4	2	4	2	4	2	2
34	4	4	4	4	3	2	2	4	4
35	3	3	3	3	4	2	4	2	2
36	4	5	5	5	2	1	5	2	2
37	3	2	3	3	5	3	3	3	3
38	3	2	4	4	4	4	4	3	4
39	5	5	5	5	4	1	4	5	5
40	4	4	4	4	2	2	2	3	3
41	4	4	4	4	2	2	2	2	2
42	4	4	3	4	5	2	4	2	4
43	3	3	4	4	4	2	3	3	4
44	4	4	4	4	2	2	2	4	4
45	4	4	4	4	4	2	2	2	2
46	3	3	4	4	4	3	3	1	2
47	4	3	4	4	2	2	2	4	4

Number	VOSE 10C	VOSE 10D	VOSE 10E	VOSE 10F	VOSE 10G	VOSE 10H	VOSE 10I	VOSE 11A	VOSE 11B
48	4	4	4	3	2	1	3	1	1
49	4	3	4	4	3	3	3	3	4
50	2	2	2	2	4	4	4	2	2
51	5	4	3	2	3	3	3	5	5
52	4	4	4	4	2	2	2	4	4
53	4	3	3	2	2	3	2	2	3
54	3	4	3	4	3	4	3	3	3
55	4	5	4	3	3	2	3	1	1
56	2	3	4	4	3	1	3	2	2
57	4	4	4	4	3	2	3	3	4
58	4	4	4	4	3	2	3	3	4
59	4	4	5	3	3	1	2	4	5
60	3	4	3	3	3	2	3	3	4
61	3	2	4	3	4	2	3	1	4
62	4	4	4	4	4	2	4	3	4
63	3	3	4	3	3	3	3	3	3
64	4	3	4	4	3	2	3	2	4
65	4	4	4	4	3	2	2	2	2
66	4	3	5	4	3	1	3	4	4
67	4	3	4	3	4	3	3	4	4
68	5	5	4	4	2	1	2	3	3
69	4	4	4	4	2	2	2	2	2
70	4	4	4	4	2	2	2	3	4
71	3	2	4	4	2	2	2	4	4
72	4	3	4	4	2	2	3	4	3
73	4	4	4	4	2	2	2	2	2
74	2	3	4	4	2	2	2	2	2
75	4	4	4	5	3	1	3	2	2
76	4	4	5	2	2	1	2	2	3
77	4	4	4	4	2	2	2	4	4
78	3	3	4	3	4	2	3	2	3
79	3	4	4	4	4	4	4	4	4
80	2	4	4	4	3	2	4	2	4
81	4	4	4	4	2	2	3	2	3
82	4	4	4	4	3	2	4	4	3
83	4	4	4	3	3	2	3	4	4
84	3	3	3	3	3	3	3	3	3
85	4	4	4	4	3	2	2	4	4
86	4	4	4	3	3	2	3	3	4
87	4	4	4	4	2	2	2	2	2
88	3	4	4	4	3	2	4	3	3
89	4	2	4	4	3	2	3	4	4
90	5	5	3	4	3	1	1	2	2
91	5	5	5	5	2	2	2	4	4
92	3	3	4	2	4	2	2	2	2
93	3	3	4	4	4	1	3	5	4
94	5	4	5	5	2	2	2	4	4

Number	VOSE 10C	VOSE 10D	VOSE 10E	VOSE 10F	VOSE 10G	VOSE 10H	VOSE 10I	VOSE 11A	VOSE 11B
95	3	4	2	3	3	3	4	3	3
96	4	4	4	4	3	2	3	2	2
97	3	4	4	4	1	1	1	4	4
98	4	4	4	4	4	4	4	4	4
99	4	3		3	4	2	5	5	4
100	5	5	5	5	4	1	4	1	3
101	5	5	5	5	3	1	2	2	4
102	3	4	3	4	2	3	3	3	4
103	4	3	4	4	3	2	3	2	4
104	4	4	5	3	3	2	3	2	3
105	4	4	4	4	4	2	3	2	3
106	5	5	5	5	1	1	1	4	3
107	4	3	3	4	2	2	3	4	4
108	3	3	3	3	3	3	3	3	3

Number	VOSE 11C	VOSE 11D	VOSE 11E	VOSE 12A	VOSE 12B	VOSE 12C	VOSE 12D	VOSE 12E	VOSE 13A
1	3	1	2	5	5	1	1	1	4
2	2	5	5	5	5	1	1	1	4
3	4	2	2	4	4	2	2	2	4
4	3	3	3	3	3	3	3	3	3
5	3	2	1	4	4	2	2	2	4
6	4	2	4	4	4	2	2	2	2
7	5	1	1	5	5	1	1	2	4
8	3	3	3	3	3	3	3	3	3
9	3	2	3	4	4	2	4	4	3
10	4	3	4	4	4	2	2	2	4
11	3	2	3	4	4	2	2	2	4
12	3	3	3	4	4	2	2	2	3
13	5	1	1	5	4	1	1	1	5
14	3	4	4	4	4	2	2	2	4
15	2	4	4	4	5		2	2	5
16	5	3	4	4	5	1	2	2	4
17	4	4	1	5	5	1	1	1	5
18	3	4	4	4	4	2	2	2	3
19	3	4	4	4	4	2	2	2	4
20	2	2	4	4	4	2	2	2	4
21	2	4	4	5	4	2	2	2	4
22	2	4	4	4	4	2	2	3	4
23	4	2	2	4	4	2	2	2	5
24	3	2	4	5	5	1	2	2	5
25	2	4	2	4	4	2	2	2	4
26	2	3	3	4	4	1	1	1	4
27	3	5	5	5	4	2	2	2	5
28	2	4	5	5	4	2	3	2	5
29	4	4	4	4	4	2	2	2	4
30	5	2	2	4	4	4	2	2	4
31	4	4	5	4	3	2	3	3	4
32	2	3	4	4	4	2	2	2	4
33	2	4	4	4	4	2	2	2	4
34	4	4	4	4	4	2	3	2	4
35	3	4	4	3	4	2	2	3	4
36	3	5	5	5	5	2	2	2	5
37	2	3	3	3	3	2	2	2	4
38	3	3	3	4	3	5	5	4	4
39	4	1	4	5	5	1	1	1	5
40	4	3	3	4	4	2	2	2	4
41	2	4	4	4	4	3	3	3	4
42	4	3	4	5	4	2	2	2	4
43	3	2	4	5	5	1	2	2	5
44	4	2	2	4	4	2	2	2	4
45	2	4	4	4	4	2	2	2	4
46	1	3	3	5	5	1	1	1	4
47	4	2	2	4	4	2	2	2	4

Number	VOSE 11C	VOSE 11D	VOSE 11E	VOSE 12A	VOSE 12B	VOSE 12C	VOSE 12D	VOSE 12E	VOSE 13A
48	1	5	4	5	4	1	3	2	4
49	3	3	3	4	3	3	3	3	4
50	2	4	4	4	4	2	2	2	2
51	2	1	3	4	5	5	4	3	4
52	4	2	4	4	4	2	2	2	4
53	4	3	3	3	4	2	4	3	2
54	3	4	3	2	3	3	3	4	2
55	2	5	4	4	4	2	2	1	4
56	2	2	3	4	3	1	2	1	4
57	2	4	3	4	4	2	3	2	4
58	2	4	3	4	4	2	3	2	4
59	2	1	2	5	5	1	1	1	3
60	4	3	3	4	3	3	2	3	3
61	3	2	5	2	4	3	4	3	2
62	4	3	4	4	4	2	2	2	4
63	2	4	3	4	3	3	3	3	4
64	2	4	4	4	4	2	2	2	4
65	2	3	4	4	4	2	2	2	4
66	2	2	4	5	5	1	1	1	2
67	3	4	4	4	2	3	4	4	4
68	3	4	4	4	4	3	2	2	4
69	2	4	4	4	4	2	2	2	4
70	3	2	2	4	4	2	2	2	4
71	4	2	2	4	4	2	2	2	4
72	2	4	3	5	4	3	2	3	4
73	2	4	4	4	4	2	2	2	4
74	2	2	4	4	4	2	2	2	4
75	3	3	3	4	4	2	2	2	4
76	2	4	5	5	5	1	1	1	5
77	3	2	2	4	4	2	2	2	4
78	2	2	2	4	4	1	2	1	4
79	4	3	4	3	4	4	3	4	4
80	2	4	4	4	4	4	2	2	4
81	2	4	4	4	4	2	2	2	4
82	4	3	3	3	4	3	3	3	3
83	4	2	2	4	4	2	2	2	4
84	3	3	3	3	3	3	3	3	3
85	4	2	2	4	4	2	2	2	4
86	4	2	2	4	4	2	2	3	4
87	2	2	4	5	5	2	1	1	4
88	3	4	4	4	4	2	2	2	4
89	2	4	4	4	4	2	2	2	4
90	3	5	5	5	4	3	2	2	5
91	4	2	2	5	5	2	2	2	4
92	2	2	2	4	4	5	2	3	5
93	2	2	2	4	4	1	1	1	3
94	5	1	1	4	4	1	4	1	5

Number	VOSE 11C	VOSE 11D	VOSE 11E	VOSE 12A	VOSE 12B	VOSE 12C	VOSE 12D	VOSE 12E	VOSE 13A
95	2	2	2	5	3	4	2	2	4
96	2	4	5	4	4	2	2	2	5
97	3	3	3	4	4	1	1	1	5
98	4	4	4	5	4	4	4	4	1
99	4	2	4	4	4	1	2	2	2
100	4	3	5	5	5	1	1	1	5
101	3	4	4	4	4	2	2	2	4
102	3	3	4	5	5	1	1	1	4
103	2	4	4	4	4	2	2	1	4
104	2	3	4	5	4	2	2	3	4
105	2	4	4	4	4	2	3	2	4
106	3	4	4	5	5	1	1	1	5
107	3	3	3	4	4	2	2	2	4
108	3	3	3	3	3	3	3	3	3

Number	VOSE 13B	VOSE 13C	VOSE 13D	VOSE 14A	VOSE 14B	VOSE 14C	VOSE 14D	VOSE 14E	VOSE 14F
1	4	1	2	4	2	2	5	4	4
2	4	4	4	5	5	5	5	1	1
3	4	2	2	3	4	4	4	3	3
4	3	3	3	3	4	4	4	4	3
5	4	3	2	5	3	4	4	2	2
6	4	2	2		5	5	5	4	1
7	4	2	1	2	4	4	4	4	4
8	3	3	3	3	3	3	3	3	3
9	3	3	3	3	3	3	3	3	3
10	4	1	1	5	4	4	4	2	2
11	4	2	2	2	4	4	4	3	2
12	3	3	3	3	3	3	3	3	3
13	5	1	1	4	3	3	4	5	4
14	4	2	3	4	4	4	4	2	2
15	4	2	2	4	4	4	4	4	4
16	4	1	1	5	4	4	4	2	2
17	5	2	2	4	4	4	4	2	2
18	4	2	2	4	4	4	4	3	2
19	4	2	2	4	4	4	4	4	3
20	4	3	3	5	5	4	4	1	1
21	4	3	3	5	4	4	4	2	2
22	4	3	2	3	4	4	4	2	2
23	5	1	1	1	3	3	3	4	4
24	5	2	2	5	5	3	4	2	4
25	4	2	2	3	4	4	2	2	2
26	4	2	2	3	4	4	4	2	2
27	4	3	2	4	3	4	4	2	2
28	5	1	2	5	5	4	4	2	2
29	4	2	2	4	3	4	4	2	3
30	4	2	1	4	4	4	4	4	2
31	5	4	3	4	5	3	4	4	3
32	4	2	2	4	4	3	4	3	4
33	4	2	3	4	4	4	4	2	2
34	4	2	2	3	2	4	4	4	4
35	4	2	2	3	3	3	3	3	3
36	4	2	3						
37	4	2	3	3	3	3	3	2	3
38	4	4	3	4	4	4	4	4	4
39	5	1	1	5	4	4	4	5	4
40	4	2	2	2	3	4	4	4	4
41	4	2	2	4	3	4	4	2	2
42	4	2	2	4	3	4	4	3	4
43	5	1	1	4	4	4	5	2	2
44	4	2	2	4	4	4	4	2	2
45	4	2	2	4	4	4	4	2	2
46	4	3	3	2	2	3	3	4	4
47	4	2	2	4	4	4	3	2	2

Number	VOSE 13B	VOSE 13C	VOSE 13D	VOSE 14A	VOSE 14B	VOSE 14C	VOSE 14D	VOSE 14E	VOSE 14F
48	4	2	2	3	4	4	3	4	2
49	3	3	3	2	2	2	4	4	4
50	2	4	4	5	4	4	4	2	2
51	3	2	3	3	4	4	3	3	2
52	4	2	2	4	4	4	4	3	4
53	3	4	3	3	4	2	3	4	3
54	4	3	3	3	3	2	4	3	3
55	4	2	2	4	4	4	4	2	2
56	3	2	1	3	4	3	4	2	2
57	4	2	2	4	3	3	3	4	3
58	4	2	2	4	3	3	3	4	3
59	4	3	2	5	5	4	5	2	2
60	3	3	3	3	3	4	3	4	3
61	4	3	5	2	3	2	4	3	3
62	4	2	2	5	4	4	4	2	2
63	4	3	3	3	4	3	3	2	3
64	4	3	3	4	4	4	4	3	3
65	4	2	2	4	4	4	4	3	3
66	2	4	4	5	4	5	5	1	1
67	4	3	3	3	4	4	4	3	3
68	4	3	1	4	3	4	3	2	4
69	4	2	2	3	3	3	3	3	3
70	4	2	2	4	4	4	4	4	4
71	4	2	2	4	4	4	4	2	2
72	4	1	1	4	4	3	4	2	3
73	4	2	2	3	3	3	3	3	3
74	4	2	2	5	5	5	5	1	1
75	4	2	1	5	5	5	5	1	1
76	5	1	1	4	4	5	4	1	1
77	4	2	2	5	5	4	4	2	2
78	3	2	2	4	4	4	4	3	3
79	4	4	4	4	4	3	3	4	4
80	4	2	2	3	4	2	4	2	2
81	4	2	2	4	4	4	4	3	2
82	4	2	2	4	4	4	4	3	3
83	4	2	2	5	5	4	4	2	2
84	3	3	3	3	3	3	3	3	3
85	3	3	2	4	3		3	3	2
86	4	2	2	4	3	4	3	2	3
87	4	2	1	4	4	5	2	4	4
88	4	3	2	2	3	4	4	3	4
89	4	2	2	4	4	4	4	2	2
90	5	3	3	4	3	4	3	4	4
91	4	2	3	4	4	4	3	3	3
92	4	4	3	5	3	4	4	2	4
93	3	3	3	4	3	4	3	2	2
94	4	2	2	3	2	4	4	5	5

Number	VOSE 13B	VOSE 13C	VOSE 13D	VOSE 14A	VOSE 14B	VOSE 14C	VOSE 14D	VOSE 14E	VOSE 14F
95	2	3	2	4	3	3	3	4	3
96		1	1	4	3	4	3	1	3
97	5	1	1	5	4	4	5	2	4
98	4	4	3	4	4	4	4	4	4
99	2	4	4	2	4	3	3	4	4
100	5	2	2	5	4	3	5	2	4
101	4	2	2	5	4	4	4	2	2
102	4	2	2	4	4	4	4	4	4
103	4	1	1	3	3	2	4	3	2
104	5	2	2	3	3	4	4	2	2
105	4	2	2	4	4	4	4	2	2
106	5	1	1	5	5	5	4	5	5
107	4	2	2	5	4	4	5	2	2
108	3	3	3	3	3	3	3	3	3

Number	VOSE 14G	VOSE 15A	VOSE 15B	VOSE 15C	VOSE 15D	VOSE 15E	VOSE 15F	VOSE 15G	VOSE 15H
1	2	2	2	2	4	4	4	5	2
2	5	5	5	5	5	1	1	5	5
3	3	4	4	4	4	2	2	2	2
4	3	3	4	4	3	3	4	3	4
5	2	4	4	4	4	2	2	2	3
6	3	5	5	5	5	4	1	4	3
7	3	4	4	4	4	2	2	4	3
8	3	3	3	3	3	3	3	3	3
9	3	3	3	3	3	3	3	3	3
10	1	5	4	4	4	2	2	4	4
11	2	2	2	2	4	4	3	4	3
12	3	3	3	3	3	3	3	3	3
13	2	3	3	2	4	4	4	4	2
14	4	4	4	4	4	2	2	3	3
15	2	5	4	4	4	2	2	2	2
16	3	5	4	4	4	1	2	5	3
17	2	4	4	4	4	2	2	2	4
18	2	4	4	4	4	3	2	2	3
19	3	4	4	3	3	4	3	4	4
20	2	5	5	5	4	1	1	2	4
21	3	5	5	4	4	2	2	2	3
22	3	4	4	3	4	2	2	4	2
23	2	2	3	2	3	4	4	4	2
24	1	5	5	3	4	2	1	5	5
25	2	2	4	4	2	2	2	4	4
26	2	4	4	4	4	2	2	2	3
27	3	5	3	4	2	3	1	4	4
28	1	5	4	4	4	2	2	4	5
29	3	4	4	4	4	3	3	3	3
30	1	4	2	2	3	4	4	4	4
31	4	3	4	2	2	3	4	5	4
32	2	4	4	3	4	3	2	4	4
33	2	4	4	4	4	2	2	4	3
34	3	4	4	4	4	4	5	4	3
35	3	3	3	3	3	3	3	3	3
36		3	2	4		3	3	3	3
37	3	3	3	3	3	2	3	3	2
38	4	4	5	5	5	5	5	5	5
39	3	5	2	4	5	5	2	5	3
40	4	4	4	4	4	2	2	3	4
41	3	4	2	4	4	2	2	4	4
42	4	4	3	4	4	3	4	3	4
43	1	4	4	4	5	2	2	3	4
44	2	4	4	4	4	2	2	2	3
45	2	4	4	4	4	2	2	2	3
46	3	3	2	2	3	5	5	5	3
47	2	5	5	5	5	2	2	2	2

Number	VOSE 14G	VOSE 15A	VOSE 15B	VOSE 15C	VOSE 15D	VOSE 15E	VOSE 15F	VOSE 15G	VOSE 15H
48	1	2	2	2	3	5	5	5	4
49	2	3	3	3	3	3	4	3	3
50	2	4	4	4	4	2	2	2	2
51	3	3	4	2	3	3	4	2	3
52	2	4	4	4	4	3	3	4	4
53	2	3	3	4	4	3	2	4	2
54	2	3	3	3	3	2	4	3	2
55	2	4	4	4	4	2	2	3	3
56	2	4	4	4	4	2	2	3	4
57	2	4	3	3	3	4	4	4	3
58	2	4	3	3	3	4	4	4	3
59	3	5	5	5	5	2	2	4	4
60	3	3	2	3	3	4	3	4	4
61	3	3	3	4	4		2	3	4
62	2	4	4	4	4	2	2	3	4
63	2	2	2	3	3	4	3	3	3
64	3	4	4	4	4	2	2	2	4
65	1	4	4	4	4	2	2	4	3
66	2	5	4	4	5	1	1	3	2
67	2	4	4	3	3	4	3	4	4
68	3	4	3	3	4	4	3	2	3
69	3	3	3	3	3	3	3	3	3
70	3	2	2	3	4	4	4	4	4
71	2	4	4	4	4	2	2	4	4
72	3	4	4	3	4	2	2	3	3
73	3	3	3	3	3	3	3	3	3
74	1	5	5	5	5	1	1	4	2
75	1	5	5	5	5	1	1	4	5
76	1	4	4	4	4	2	2	4	4
77	2	5	5	5	4	2	2	2	4
78	3	4	4	4	4	3	3	4	4
79	3	3	3	3	4	4	4	4	4
80	4	4	4	2	4	3	3	4	4
81	2	4	4	2	4	3	3	4	4
82	2	4	4	4	4	3	3	4	4
83	2	5	5	4	4	2	2	3	3
84	3	3	3	3	3	3	3	3	3
85	3	4	3	4	3	4	2	4	3
86	3	4	3	4	3	1	2	3	4
87	2	4	4	4	2	1	1	1	3
88	3	4	3	4	4	4	4	4	3
89	1	4	4	4	4	2	2	3	4
90	2	3	2	4	3	4	2	3	4
91	3	4	3	4	4	4	3	4	4
92	4	5	4	4	4	2	4	4	3
93	2	4	3	3	2	3	4	4	3
94	3	3	4	4	4	5	5	5	3

Number	VOSE 14G	VOSE 15A	VOSE 15B	VOSE 15C	VOSE 15D	VOSE 15E	VOSE 15F	VOSE 15G	VOSE 15H
95	3	4	3	2	2	3	3	2	3
96	3	5	4	4	3	1	3	4	4
97	3	2	2	2	2	4	4	4	1
98	4	2	2	2	2	2	2	2	2
99	4	2	4	3	2	4	4	4	4
100	3	5	3	3	5	1	2	5	4
101	2	5	5	5	5	2	2	3	3
102	1	4	4	4	4	4	4	4	4
103	3	3	4	2	3	3	4	4	4
104	2	3	3	4	4	2	2	4	4
105	2	4	4	4	4	2	2	2	3
106	1	5	3	4	4	3	2	2	4
107	2	5	4	4	5	2	2	4	2
108	3	3	3	3	3	3	3	3	3

Number	VOSE 15I	Exam 1	Exam 2	Exam 3	Exam 4	Exam 5	Exam 6	Exam 7	Exam 8
1	3	50	50	45	45	50	50	40	35
2	1	35	35	25	30	25	20	20	20
3	3	20	15	30	25	35	15	45	15
4	4	35	35	25	35	35	35	30	25
5	2	50	45	35	35	40	25	45	15
6	3	30	30	10	30	25	5	30	10
7	3	50	50	50	45	45	45	45	40
8	3	50	45	40	45	50	35	45	25
9	3	30	35	35	20	35	25	15	15
10	2	50	50	45	40	45	45	40	40
11	3	20	40	25	30	35	20	40	25
12	3	30	40	15	25	30	35	40	15
13	2	45	50	40	40	50	50	45	35
14	3	25	15	25	25	35	10	25	5
15	2	45	45	45	50	45	50	50	45
16	3	30	35	25	35	35	40	45	25
17	2	40	30	35	30	45	30	35	35
18	3	40	35	30	20	40	35	30	30
19	3	10	15	15	15	30	10	20	0
20	2	50	50	45	40	45	45	45	40
21	3	45	50	35	40	45	45	40	30
22	4	45	30	25	35	40	40	45	25
23	2	45	50	35	35	40	25	40	20
24	2	40	40	40	30	40	45	40	35
25	2	45	50	35	40	40	25	45	40
26	1	30	40	20	25	40	20	25	30
27	4	40	45	30	40	40	50	30	30
28	1	50	50	40	50	35	50	45	25
29	3	40	40	35	40	40	35	40	25
30	1	20	30	35	25	45	35	35	35
31	3	35	25	25	30	40	30	45	40
32	2	50	50	35	35	40	40	45	35
33	3	45	50	50	45	35	35	45	35
34	4	35	50	30	45	45	30	35	35
35	3	30	30	35	30	20	25	25	10
36	4	35	35	30	25	40	10	25	10
37	2	50	45	45	40	45	40	45	40
38	5	45	50	50	45	45	50	45	35
39	3	40	15	20	20	15	20	20	10
40	3	25	20	15	25	20	15	30	25
41	3	35	35	15	20	45	30	35	10
42	4	30	35	30	20	40	50	45	40
43	1	30	35	25	40	50	20	45	40
44	2	25	45	35	20	40	35	40	30
45	3	40	30	35	30	45	40	50	35
46	3	30	50	30	35	40	40	45	20
47	2	45	50	30	40	40	45	45	35

Number	VOSE 15I	Exam 1	Exam 2	Exam 3	Exam 4	Exam 5	Exam 6	Exam 7	Exam 8
48	1	45	50	40	30	35	45	35	25
49	3	35	45	35	45	45	50	45	40
50	2	30	5	20	15	25	25	20	25
51	4	40	35	20	30	25	25	40	25
52	2	45	45	50	40	45	50	40	45
53	3	25	30	15	25	15	25	5	5
54	3	25	40	15	25	25	15	10	5
55	2	30	35	20	20	35	35	40	25
56	2	40	45	40	40	45	45	35	35
57	2	45	45	50	50	50	45	50	35
58	2	25	30	30	45	45	50	50	35
59	3	35	50	35	35	45	50	40	40
60	3	40	40	35	35	20	25	10	5
61	3	40	45	30	15	25	35	50	15
62	3	50	40	30	40	40	35	40	25
63	3	20	20	25	30	40	30	20	10
64	2	30	25	15	15	25	20	30	20
65	2	45	40	30	35	40	45	45	40
66	2	35	25	35	35	45	25	45	35
67	3	30	25	30	25	35	30	40	25
68	4	35	30	25	20	25	25	30	10
69	3	25	20	10	10	20	25	30	15
70	3	30	50	35	40	50	35	40	20
71	4	50	45	35	35	45	20	35	30
72	3	50	35	40	35	50	35	45	30
73	3	35	45	30	35	10	15	30	20
74	2	20	15	10	15	10	15	30	5
75	3	40	25	40	30	30	25	35	25
76	3	50	50	50	45	50	50	45	30
77	2	25	25	35	45	45	40	35	40
78	2	45	40	35	40	40	45	35	25
79	2	30	25	10	35	25	15	25	5
80	3	35	40	25	30	40	40	40	25
81	2	35	25	10	25	30	10	35	30
82	2	45	50	50	45	50	50	35	35
83	2	50	50	45	45	50	50	45	35
84	3	35	25	25	35	35	35	35	20
85	3	35	25	35	25	25	25	25	15
86	2	25	50	35	30	45	40	40	30
87	3	45	45	25	40	40	50	45	35
88	3	25	30	35	25	40	30	25	15
89	2	40	30	30	40	40	20	45	30
90	3	30	25	5	20	30	40	30	20
91	3	35	30	30	30	45	25	35	25
92	3	40	45	30	35	45	35	45	45
93	3	45	50	45	40	50	35	40	40
94	3	45	50	45	30	25	25	35	40

Number	VOSE 15I	Exam 1	Exam 2	Exam 3	Exam 4	Exam 5	Exam 6	Exam 7	Exam 8
95	4	40	45	45	40	50	45	35	40
96	3	30	45	30	40	35	45	25	30
97	2	30	35	30	40	40	45	40	25
98	2	40	45	35	35	40	45	30	10
99	3	40	45	35	35	30	45	50	20
100	3	40	45	35	30	40	35	45	25
101	3	25	45	30	30	40	30	40	35
102	2	35	30	30	35	40	40	50	35
103	2	45	40	40	30	40	40	50	25
104	2	50	50	35	40	40	25	35	30
105	2	35	30	35	35	45	25	35	25
106	5	40	35	25	35	40	35	45	30
107	2	50	45	40	50	45	40	40	40
108	3	50	45	45	45	45	45	30	35

Number	Recitation 1	Recitation 2	Recitation 3	Recitation 4	Recitation 5	Recitation 6	Recitation 7	Recitation 8	Recitation 9
1	9	10	9	10	10	0	10	10	10
2	9	10	9	10	9	10	10	10	10
3	9	10	9	9	10	10	10	10	9
4	9	10	9	9	10	10	10	10	10
5	9	10	9	10	10	10	10	10	9
6	9	10	9	9	9	10	10	10	10
7	0	10	9	10	10	10	10	10	10
8	9	10	9	10	9	0	10	10	10
9	8	10	9	8	7	10	10	10	9
10	9	10	9	0	9	0	10	10	10
11	0	10	9	10	8	0	10	10	10
12	9	10	9	9	9	0	10	10	0
13	9	10	9	10	9	0	10	10	0
14	9	10	9	10	9	10	10	10	10
15	9	10	9	10	10	10	10	10	10
16	9	0	10	10	10	10	10	10	10
17	10	10	10	10	10	10	10	8	10
18	8	10	0	0	0	10	10	0	0
19	10	8	9	10	10	10	10	9	10
20	10	10	10	10	10	10	10	10	10
21	10	10	10	10	10	10	10	8	10
22	8	10	10	10	0	10	10	10	10
23	10	9	10	10	10	10	10	10	5
24	9	9	9	10	10	10	10	10	10
25	10	10	10	10	10	0	10	10	10
26	7	10	10	10	10	10	10	10	10
27	10	10	0	0	10	10	10	9	10
28	10	10	10	10	10	10	10	8	5
29	8	10	9	10	10	10	10	10	10
30	9	9	9	10	10	10	10	10	10
31	9	9	0	0	0	10	10	10	10
32	10	9	10	9	10	9	10	8	10
33	8	9	10	9	10	9	10	9	10
34	9	8	10	9	10	10	10	8	10
35	8	7	10	9	10	8	10	10	10
36	8	8	10	9	10	8	10	8	10
37	10	9	10	9	10	9	10	8	10
38	10	9	10	9	10	9	10	8	10
39	8	0	10	9	9	9	10	9	10
40	9	8	10	9	10	8	10	8	10
41	9	9	10	0	0	10	10	9	10
42	8	9	10	9	10	10	10	9	10
43	10	10	0	0	0	10	10	8	10
44	10	10	10	9	10	9	10	8	10
45	10	10	10	10	9	10	10	10	10
46	8	9	10	10	10	10	10	10	10
47	10	10	10	10	9	10	10	10	10

Number	Recitation 1	Recitation 2	Recitation 3	Recitation 4	Recitation 5	Recitation 6	Recitation 7	Recitation 8	Recitation 9
48	10	9	10	10	9	10	10	10	10
49	10	10	10	10	10	10	7	8	10
50	8	8	10	8	9	10	8	10	9
51	9	10	10	10	10	10	10	10	10
52	10	10	10	10	9	10	10	10	10
53	10	9	10	10	9	10	10	10	10
54	8	10	10	10	9	10	10	10	10
55	8	10	10	10	10	10	10	10	10
56	10	10	10	10	10	10	10	10	10
57	8	10	10	10	9	10	10	10	10
58	8	10	10	10	9	10	10	10	10
59	8	10	10	9	10	10	8	10	10
60	8	10	10	10	10	10	10	10	10
61	9	9	9	10	10	10	0	10	10
62	9	9	10	0	10	10	10	10	10
63	9	9	10	10	10	10	0	10	10
64	9	9	0	0	10	10	10	10	10
65	9	9	9	10	10	0	10	10	10
66	9	9	9	10	10	10	10	10	10
67	9	9	0	0	10	0	10	10	10
68	0	9	9	10	10	10	10	10	10
69	9	9	10	10	10	0	10	10	10
70	9	10	10	10	10	10	10	10	0
71	10	9	9	10	10	10	10	10	10
72	10	10	8	9	10	10	10	10	10
73	10	10	10	10	10	9	10	0	10
74	10	10	10	10	10	0	9	10	10
75	10	10	10	10	10	9	10	10	10
76	10	9	8	10	10	10	8	10	10
77	9	10	10	9	10	10	10	0	0
78	10	10	10	9	10	10	10	10	10
79	10	9	8	10	10	10	0	10	0
80	10	10	10	9	10	9	10	10	10
81	9	10	10	10	10	10	10	10	0
82	9	10	10	10	10	10	9	10	10
83	9	10	10	10	10	10	9	0	10
84	9	10	10	10	10	10	0	10	10
85	10	8	8	8	10	6	10	0	10
86	9	9	8	10	10	10	10	9	10
87	10	10	9	7	0	0	10	7	10
88	10	9	8	7	9	10	10	7	10
89	10	10	9	7	9	10	10	8	10
90	10	10	10	9	10	10	10	10	10
91	10	10	8	10	0	10	10	0	10
92	10	10	0	9	10	10	10	8	10
93	10	10	10	9	10	10	10	10	10
94	10	10	9	10	10	10	10	9	10

Number	Recitation 1	Recitation 2	Recitation 3	Recitation 4	Recitation 5	Recitation 6	Recitation 7	Recitation 8	Recitation 9
95	0	9	9	9	10	9	10	10	10
96	10	10	9	7	9	10	10	7	10
97	9	10	10	10	9	10	10	10	10
98	10	10	10	9	9	10	8	10	10
99	10	10	10	10	9	10	10	10	10
100	10	10	10	9	9	10	10	10	10
101	8	10	10	9	9	10		10	
102	10	10	10	10	9	10	10	10	
103	10	10	10	9	9	10	9	10	10
104	9	10	10	0	10	9		10	
105	9	10	10	10	10	10	10	10	10
106	10	10	9	10	9	10	10	10	10
107	10	10	10	10	10	10	10	10	10
108	10	10	10	9	9	10	8	10	10

Number	Recitation 10	GI Lab 1	GI Lab 2	GI Lab 3	OI Lab 1	GI Lab 4	OI Lab 2	GI Lab 5	OI Lab3
1	10	10	15	15	14	15	15	15	15
2	10	10	15	14	14	15	15	15	15
3	10	10	12	13	13	15	15	14	15
4	10	9	12	11	12	12	14	15	12
5	10	10	12	14	13	14	15	15	15
6	10	9	14	15	13	14	15	15	14
7	10	9	14	15	14	15	15	15	15
8	10	9	15	15	13	14	14	13	15
9	10	9	12	13	11	13	14	12	12
10	10	7	15	15	13	15	15	15	13
11	10	7	15	15	15	15	15	15	15
12	10	6	12	12	12	12	13	12	12
13	10	8	14	13	0	13	14	13	11
14	10	10	12	14	12	13	15	15	15
15	10	9	15	15	14	15	15	15	15
16	9	9	14	12	12	12	12	14	14
17	10	10	14	15	14	13	14	14	14
18	10	7	14	15	9	11	10	0	13
19	0	8	11	10	9	12	15	14	13
20	9	9	14	13	10	14	13	13	14
21	0	9	15	14	13	15	13	15	14
22	0	9	14	10	14	14	12	12	15
23	10	10	14	12	12	14	12	15	13
24	10	8	12	13	9	15	12	14	14
25	9	9	14	13	10	14	13	13	14
26	8	9	14	12	15	13	13	13	14
27	9	8	15	14	11	12	15	14	15
28	0	8	15	14	11	15	15	14	15
29	10	10	14	15	14	13	14	14	14
30	0	8	12	13	9	14	12	14	13
31	10	9	14	12	12	15	15	14	14
32	8	9	14	14	15	14	14	14	15
33	10	9	13	13	15	13	15	14	15
34	0	10	14	14	15	14	15	15	14
35	0	10	13	12	14	10	13	13	15
36	10	10	14	14	15	14	15	15	14
37	8	9	14	14	15	14	14	14	15
38	9	10	14	13	15	13	13	15	11
39	10	7	13	13	12	13	0	14	15
40	10	10	14	14	15	14	15	15	14
41	10	8	12	12	14	13	14	13	0
42	10	9	12	12	13	13	14	13	13
43	10	10	0	12	13	14	0	13	14
44	9	10	14	13	15	13	13	15	11
45	10	9	15	15	14	15	15	15	15
46	9	9	15	15	14	15	15	15	15
47	10	9	15	15	14	15	15	15	13

Number	Recitation 10	GI Lab 1	GI Lab 2	GI Lab 3	OI Lab 1	GI Lab 4	OI Lab 2	GI Lab 5	OI Lab3
48	9	8	15	13	14	14	15	14	14
49	10	6	9	13	13	12	12	12	14
50	8	7	13	13	12	14	15	13	13
51	9	8	15	15	14	15	15	15	13
52	10	9	15	15	14	15	15	15	15
53	9	8	15	13	12	14	15	14	14
54		8	15	15	15	15	15	13	12
55	9	9	15	15	14	15	15	15	15
56	10	10	15	15	15	14	15	13	15
57	10	10	15	15	15	15	15	15	15
58	10	10	15	15	15	15	15	15	15
59	9	10	15	15	14	15	15	15	15
60		6			14	15	15	13	
61	10	8	12	11	14	13	15	14	15
62	10	8	12	12	13	15	14	12	13
63	10	8	13	12	12	15	14	0	13
64	10	8	13	14	13	13	14	11	12
65	10	7	13	12	15	14	15	13	13
66	10	9	12	14	14	12	15	11	14
67	10	7	10	0	12	13	12	0	11
68	10	8	12	11	14	12	14	14	15
69	10	9	13	14	13	13	14	11	15
70	9	9	14	13	13	13	12	12	15
71	9	10	14	13	14	14	14	15	12
72	9	9	14	13	13	12	12	13	7
73	10	9	14	12	13	12	11	11	13
74	8	8	12	15	12	0	8	15	0
75	10	9	14	13	13	12	14	11	14
76	9	10	15	13	13	14	12	13	7
77	9	9	14	13	13	12	12	12	12
78	7	8	12	15	12	0	8	15	8
79	9	10	14	13	14	12	14	0	0
80	10	6	14	14	10	13	7	5	15
81	8	9	15	12	11	12	11	12	13
82	9	10	14	13	12	12	11	13	10
83	9	10	15	13	13	14	14	12	11
84	0	8	11	13	10	13	14	12	0
85	7	8	12	9	14	12	14	11	8
86	9	9	13	12	13	14	14	15	15
87	9	10	14	13	14	14	15	14	15
88	9	9	9	13	14	14	15	14	14
89	8	10	9	13	12	13	13	15	14
90	8	10	14	14	15	14	15	15	14
91	9	8	12	9	14	12	14	11	8
92	9	9	14	10	12	14	11	14	14
93	0	10	14	14	15	14	15	15	14
94	0	10	14	12	14	13	13	14	13

Number	Recitation 10	GI Lab 1	GI Lab 2	GI Lab 3	OI Lab 1	GI Lab 4	OI Lab 2	GI Lab 5	OI Lab3
95	8	0	13	13	14	14	14	14	14
96	0	10	14	13	14	14	15	14	15
97		8	14	15	14	15	15	15	15
98	9	10	14	15	15	15	15	15	15
99	10	10	15	15	12	15	15	15	15
100	9	7	15	15	15	11	13	15	12
101		10	11	13	8	14	12		12
102	9	10	15	12	8	14	12	15	14
103	8	7	15	14	8	14	13	13	12
104		10	0	15	15	15	15	15	15
105	9	7	13	12	10	15	12	15	14
106	10	10	14	12	12	15	15	14	14
107	10	10	15	15	15	15	15	15	15
108	9	10	14	15	10	14	13	15	13

Number	GI Lab 6	GI Lab 7	OI Lab 4
1	15	15	15
2	14	14	15
3	14	13	14
4	12	11	13
5	13	15	15
6	10	14	15
7	11	15	13
8	12	15	15
9	12	11	14
10	15	15	15
11	12	15	13
12	10	11	12
13	12	15	13
14	9	15	15
15	15	14	15
16	14	12	11
17	5	13	12
18	12	9	9
19	7	9	12
20	13	11	12
21	15	15	13
22	12	13	13
23	14	13	13
24	15	10	11
25	14	11	12
26	12	11	12
27	14	12	0
28	15	12	11
29	15	13	12
30	14	10	11
31	10	12	11
32	13	14	13
33	15	14	12
34	13	15	14
35	14	12	11
36	15	15	14
37	15	14	13
38	15	14	13
39	12	14	12
40	11	15	14
41	9	12	9
42	14	12	9
43	15	12	12
44	14	14	13
45	15	15	15
46	15	15	15
47	11	15	13

Number	GI Lab 6	GI Lab 7	OI Lab 4
48	14	15	15
49	15	12	10
50	12	14	13
51	12	15	13
52	15	15	15
53	14	15	15
54	13	15	15
55	15	15	15
56	15	15	15
57	15	15	15
58	15	15	15
59	15	15	15
60		15	
61	11	13	0
62	13	14	14
63	13	14	14
64	13	13	12
65	12	11	15
66	13	12	12
67	11	14	11
68	13	12	13
69	12	13	13
70	15	12	13
71	14	13	12
72	12	13	12
73	11	10	10
74	10	12	15
75	14	10	10
76	14	13	12
77	13	12	13
78	15	12	15
79	14	0	0
80	14	13	12
81	15	9	8
82	15	12	11
83	14	14	15
84	13	12	8
85	14	12	11
86	14	13	13
87	14	14	13
88	13	13	13
89	14	14	15
90	9	14	13
91	14	12	11
92	14	13	12
93	13	14	13
94	11	15	9

Number	GI Lab 6	GI Lab 7	OI Lab 4
95	15	13	9
96	13	14	13
97	13	15	15
98	14	15	15
99	11	15	15
100	13	14	15
101	15		
102	11	15	15
103	14	15	15
104	13	15	15
105	13	15	15
106	11	15	15
107	13	15	15
108	15	15	15