ABSTRACT

BEDWARD, JOHN. Young Adolescent Inquiry, Cognition and Transfer: Middle Grade Students Laboratory Experiences of Thermodynamic Concepts Applied to a Novel Situation. (Under the direction of Dr. Eric Wiebe, Dr. Brian Matthews, and Dr. Terri Varnado).

This is a transfer of learning study focused on middle school inquiry based science and technology education. Research suggests that difficult to master energy science ideas, heat and temperature, are integral to high school science learning. Theoretical discussion associated with transfer of learning as a transportation metaphor and reconceived notions of transfer as a dynamic process are intertwined with student challenges associated with cognitive load, the laboratory setting, scientific inquiry, technological problem solving, and learning progressions. The study sample of twenty-four ($N = 24$) students is from a week long summer program administered by the Science House, a North Carolina State University, research and outreach program. The dependent variables include the various student scores—pretest, posttest, mid-week transfer, and end-of-week transfer of learning scores. The independent variable is the differences in laboratory set up: physical apparatus versus computer-based simulation. The control group (Group 2) showed a gain from pretest ($M=12.17$, $SD=5.25$) to posttest ($M=13.17$, $SD=4.13$) as did the treatment group (Group 3) scores ($M=10.25$, $SD=4.55$ and $M=13.17$, $SD=3.71$, respectively). Group 2 and Group 3 showed transfer in scores of ($M=2.04$, $SD=.144$ and $M=1.71$, $SD=.689$, respectively). While Group 2 and Group 3 showed transfer out scores of ($M=.965$, $SD=.965$ and $M=2.17$, $SD=1.03$, respectively).
There was a positive linear relationship of (.366 and .398) for the control group and treatment group respectively, associated with the week long laboratory activities and the end-of-week transfer of learning task. A greater number of students, in both the control and experimental group, received higher scores on their posttest scores. Alterations in the laboratory set up changed the nature of the discourse within the student-teacher (S-T), student-student (S-S) and student-environment (S-E) groupings. In particular, Group 3 (S-E) interactions promoted rich discourse as a result of the students ability to rerun the simulation environment multiple times. The use of simulation labs as a replacement and/or add on to classic laboratory set up is promising. The study of thermodynamic concepts continues to be a challenge. Just looking at transfer of learning scores is not enough, various forms of documentation and interactions (e.g., scaffolding) are needed to draw out student reasoning. Finally, students need additional opportunities to interact with models and other forms of representation that inform understanding of natural and designed phenomena.
Young Adolescent Inquiry, Cognition and Transfer: Middle Grade Students Laboratory Experiences of Thermodynamic Concepts Applied to a Novel Situation.

by
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BIOGRAPHY

John Bedward was born and raised in Ottawa, Canada of African-Scottish-Indian-Jamaican heritage, graduating from École Secondaire Champlain and Bell High School. Over the past twenty five years John has traveled to various regions of the world including East Africa, the Caribbean, Canada, and the USA. He has worked as a provincial tennis coach for 10 years, and managed multi-million dollar sports facilities for Racquet Power Inc. In the late 1980s, he pursued his longstanding interest in design and technology by apprenticing and working for Lowe Martin printing, in their digital film lab. In 1993, he opened his own communication and consulting practice servicing clients in Natural Resources Canada, Energy and Efficiency initiative, and several private sector firms. As a consultant he managed projects and programs across an array of media including industrial video, print, and ecommerce. His professional interest in media and communication transferred into personal working associations in independent film and video production at Saw Gallery, and radio broadcasting at CKCU FM 93.1 in Ottawa. As well as creating an independent publishing label, Africanstory. From 1996 to 1999 he worked with Prospectus Inc. as a sales and marketing manager overseeing a variety of design, print and ecommerce initiatives. In 1999, he was recruited by Interpath Communication Inc., formerly a North Carolina start-up, as a product manager responsible for their business-to-business ecommerce product line. Prior to attending North Carolina State University in 2001, he worked as a marketing product manager for Nortel Networks on their software and distributed application initiatives. He is happily married for the past 15 years.
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CHAPTER ONE

INTRODUCTION

Each generation faces unique challenges. American K12 students are under pressure to outperform their peers and respective students from around the globe. Why? The United States is transforming into a knowledge economy where technological innovation and inventiveness, and new scientific discoveries are necessary ingredients to global competitiveness. Is this a fair burden on a student population, where the educational environment has not kept pace with the emerging global economy? After all, class overcrowding, the sheer number of unconnected facts imposed upon students and the varied histories of the student population make learning increasingly difficult. As Oppenheimer (2004) suggests, the low common denominator of academic goals, short class periods, the sameness of task within each class, despite the individual differences among students appear to make little sense. After 15 years of standards-based reform American students continue to fair poorly in comparison with students in other countries (Duschl, Schweingruber & Shouse, 2007). High school students’ scores from the nation’s report card, the National Assessment of Educational Progress (NAEP) show similar results (Singer & Schweingruber, 2006). Many stakeholders and public-private partnerships are pressing high school students to develop greater fluency in science, technology, engineering and mathematics (STEM). It is seen as a prerequisite to succeeding in an increasingly complex society. In essence, a re-embracing of core subjects, developing contextual learning skills and insuring information and communication technology (ICT)
literacy that augments understanding and reasoning skills (Partnership for 21st Century Skills, 2007). Overall, the academic demands on young students will continue to increase. Assisting students to meet higher expectations requires a broad and connected view of the K12 academic experience. Educators and policymakers must realize the needs of a differentiated school population—physiological, biological and physical development; and differences in cultural, historical and economic experiences, which impact exposure to science and comfort with the norms of scientific practice (Duschl et al., 2007). The middle grade students’ position is unique. They are consolidating their first years of school experiences: applying their reading, writing, and arithmetic to new content areas and developing richer cognitive connections, while engaging in complex subject matter.

Science content is a challenge as students move between reasoning concretely and abstractly with newly acquired understandings (American Association for the Advancement of Science, 1989). Often, their intellectual curiosity, science knowledge and perceptions of the physical world are in conflict (Partnership, 2007). These increased cognitive demands invite novice forms of inquiry, which quickly translate to strict protocols of inquiry based learning. As such, students are busily organizing their cognitive world and trying to utilize these experiences across many settings. Where available, the traditional science laboratory may lack the resources, setting, and/or appropriate sequencing of science instruction, resulting in scientific understanding that is disjointed and/or forgotten (Duschl et al., 2007). As one student states, “I’ve never used anything I learned in science, so no, it is not really relevant” (Linn & Hsi, 2000, CD sleeve). The
dissemination of lasting science ideas often requires several different approaches, more
time spent on fewer concepts and richer integration before students’ gain the necessary
confidence to generalize the knowledge.

At issue is the identification of enduring science ideas middle school students can
master over time, and an integrated science instruction to help organize their knowledge
and experience for future use. Students are continually transferring what they have learned
to new subject matter or new situations—it would be difficult to fully master algebra
problems without having a foundation or prior knowledge of arithmetic. Over the past 35
years science educators have observed difficulty among a full range of students in the
comprehension and application of thermodynamic concepts (Smith & Schmuckler, 1974).
Empirical studies in transfer of learning, conceptual change, reasoning, and metacognition
have been used to examine energy science misconceptions (e.g., Smith & Schmuckler,
1974; McClelland, 1989; Lewis, Stern, & Linn, 1993; Goldring & Osborne, 1994;
Brookes, Horton, Van Heuvelen & Etkina, 2005). Understanding the characteristics and
behavior of thermodynamic concepts has far reaching implications for high school biology,
chemistry, and physics students. The formal teaching of energy begins in the fourth grade
and continues throughout high school (National Research Council, 1996; North Carolina
Department of Instruction, 2004). Energy is an enduring subject matter concept that gets
mixed up with naïve notions of temperature and heat. Prior knowledge, poor integration of
textbooks with discovery experiences, and the demands of new knowledge acquisition can
also create confusion. Often, the concept of temperature, the average kinetic energy of the
atoms or molecules that make up the substance, and heat, the total kinetic energy of all the
particles that make up a substance, are used interchangeably without regard for their
respective nuances (Ferguson, 1993). This is because two substances can have the same
temperature, but have different amounts of heat energy. In the early 1990s empirical
studies focused on middle school energy science reasoning, and investigated
misconceptions associated with thermal flow, heat, temperature, and thermal transfer to
name a few (e.g., Lewis, 1991, 1993; Linn, 2000, 2004). With the advent of networked
ICT, simulation labs of energy related phenomena began influencing the instructional
approaches to further students’ scientific reasoning abilities. One area of focus for Lewis et
al. (1993) was reasoning differences and conceptual change associated with simulations
versus traditional laboratory set ups. The work of Linn (2004) with middle school students’
thermodynamic investigations demonstrates the ongoing effort to integrate ICT with
scientific inquiry and the importance of monitoring student-teacher interactions and
student reflections. In these activities, middle grade students integrate and interchange
between technological problem solving and scientific inquiry. Conventional science
laboratory set-ups and new ICT that enable real time data collection, virtual searches, and
investigation of natural phenomena require cognitive effort, technological skill, and basic
problem solving techniques. This includes problem definition, assumptions and
predictions, trial and error, troubleshooting, customization, and results analysis (Singer et
al., 2006). Educational research studies should continue to embrace the technological
literacy that encourages scientific fluency and vice versa. Technological problem solving
becomes part of the process of scientific inquiry and not the end goal. Richer and more astute technological interfaces will enable greater transparency between scientific investigation and the technology mediated environment. Learning should increase due to the richness of the techno-scientific environment. Hence, the purpose of this study is to consider whether a computer-based virtual simulation or classical science laboratory set up better prepares middle school students to transfer energy science concepts to novel inquiry problems.

THE LABORATORY AND INQUIRY

Laboratory experiences provide opportunities for students to interact directly with the material world (or with data from the material world), using tools, data collection techniques, models and theories of science (Singer et al., 2006, p. 31).

The laboratory experience offers middle grade students opportunities for subject matter mastery, a chance to further their reasoning abilities, and to develop knowledge and practical skills. Along with peer collaboration, another important goal is the deepening of their science interests and learning the murkiness of empirical pursuits. Other appropriate laboratory experiences include interactions with data drawn from the real world, access to large databases and remote access to scientific instruments and observations, enriching the students experience (Singer et al., 2006). A challenge within the laboratory setting is the cognitive demands of students as they are involved in science processes and procedures as well as theoretical aspects associated with their scientific investigation. If not structured appropriately the laboratory experience can be overwhelming. The research work of Winberg & Berg (2007) suggests that cognitive load can have a negative affect on student
learning within laboratory settings. An understanding of cognitive load theory (CLT) can shed light on the challenges and possible remedies. The inquiry process is demanding in-and-of-itself. With the changing nature of laboratory apparatus, for instance the use of virtual simulation labs, the practice of middle school scientific and technological inquiry must adapt and reflect the new demands on students.

Scientific inquiry is the diverse ways in which scientist study the natural world and also student activities that support the learning of science concepts and processes of science (Singer et al., 2006, p. 27).

The practice of scientific inquiry involves the need for evidence, refined observation, the use of instrumentation for measurements, the need to control conditions, draft hypotheses, and explain findings. If done properly the inquiry experience can be a rich setting for students to uncover patterns and anomalies, encourage critical thinking, and increase diverse student-teacher and student-environment interactions. The act of inquiry fits well with adolescent higher order thinking needs.

Weighing and interpreting evidence, constructing more and more abstract principles, applying scientific ideas to everyday problems, developing multiple representations of natural phenomena, and utilizing quantitative modeling techniques is synonymous with good inquiry (Anderson & Krathwohl, 2001). The adolescent is prepared to utilize these thinking skills. They are trying to take ownership over their learning and see themselves as constructors of knowledge. Students are beginning to realize that each discipline presents different patterns of learning, languages, rules, norms, attitude, expressed in different search ‘practices’ (Wells, Carnochan, Slayton, Allen, & Vasudeva,
They are questioning when and where to use what they have learned, and seeking deeper understanding and connections to the information they are trying to transform into meaningful experiences. Through the use of functional magnetic resonance imaging (fMRI), scientists have identified that some of the strongest neural connections are those made through real life, hands-on, minds-on experiences (Feinstein, 2006). The adolescent brain is primed for learning. Neuroscientist suggests that by encouraging various forms of transfer actually strengthens learning and other higher order thinking skills (Feinstein, 2006).

**TRANSFER OF LEARNING**

Positive transfer, the productive application of knowledge to a new problem, is a case where learning is enhanced. The ability to apply knowledge concepts and skills to novel settings is an important component to students’ immediate and future success. Wiggins & McTighe (2005) suggest understanding is about transfer. To be truly able requires the ability to transfer what we have learned to new and sometimes confusing settings. But transfer is more than just measuring whether or not students use concepts provided by the teacher. Educators must be aware of the students’ conceptual schemas—data structures that represent experiences learners’ create to organize information—as to what is transferred and under what circumstance. In this sense, transfer is defined more broadly as a complex, dynamical process where knowledge is activated and applied in response to context (Mestre, 2004). Schwartz & Martin (2004), one of the leading supporters of assessing readiness for transfer, states that preparing students for transfer—
referred to as preparation for future learning (PFL)—is a necessary element in measuring transfer of learning. According to these researchers, there is a systematic way of preparing and measuring transfer that encompasses both teacher and student centered view. Transfer takes on a more transitional approach, where the transformation of knowledge, skill and identity, the reshaping, recontextualizing, and/or redefining the problem, can occur across multiple forms of social organization (Lobato, 2006).

Though new findings continue to emerge, more research is needed. The focus of current literature on transfer is K-12 mathematics (Keiler, 2007; Schwartz & Martin, 2004; Carraher & Schliemann, 2002; Lobato & Siebert, 2002). Very few contemporary transfer studies use science or technology-based concepts as a means of testing the viability of transfer (Serpell, Boykin, Madhere, & Nasim, 2006). For example, the empirical studies conducted by Linn (2000, 2004) and Lewis (1991, 1996) are focused on conceptual change and reasoning skills, and elude to the generalizability of transfer. Hence, there is a need for further study focused on how students acquire and use the enduring ideas in science education within and across subjects. This work may have significant implications on how middle grade students are prepared for high school academic success.

The current work focuses on thermodynamic concepts related to heat, temperature, and a few tightly coupled energy concepts middle school students should muse over. For these concepts, learning can take place in a rich inquiry based laboratory environment, where physical and virtual simulations labs facilitate their reasoning skills, encourage collaboration, discussion, reflection, and interaction between peers and teachers. Such an
instructional setting may promote generalizability of knowledge that can be applied to a novel setting.

This study is a mixed method approach investigating the following questions:

1. What is the variability in learning gain scores as a result of the differences in laboratory environments?

2. How does the physical lab environment versus simulation laboratory environment affect preparedness for future learning scores?

3. How does the physical laboratory environment versus a simulation laboratory environment alter students’ transfer of learning scores?

4. How might student-teacher, student-student, and/or student-environment interactions affect students’ scores?

Middle school students are interested in rich academic challenges. They are motivated by experiences that are novel, personal, real-world, and interesting. The new economy needs equipped high school graduates for the world of work and to pursue post secondary STEM disciplines. The students’ ability to apply newly acquired knowledge and skills demonstrates cognitive flexibility and understanding. Enduring ideas might be seen as the cornerstone of how pedagogy is organized, delivered, and assessed. Learning is a complex and dynamic process; therefore, transfer of learning cannot occur in a vacuum. A rich inquiry based laboratory environment may be an ideal place to facilitate scientific reasoning, technological problem solving, transfer of learning, and spur new ways of collaboration and group interaction. The integration of ICT may enable students to free up
cognitive resources that are then used to further scientific understanding. As well, technological mediation may alter their observational perceptions, increasing their curiosity and motivation. Thirty-five motivated students will participate in this week long study. Incentives in the form of books and electronic devices will be given to the top performing students. Attendance, learning gain and transfer of learning scores will serve as the benchmarks for rating student performance.
CHAPTER TWO
LITERATURE REVIEW

This chapter is concerned with the intersection between transfer of learning, the laboratory as a space for scientific and technological inquiry, and adolescent conceptual understanding of thermodynamic concepts that carry over into later school grades. Transfer theory is influenced by definition, time and educational context. For this reason, a brief historical overview outlining three major views—classical, cognitive and emergent—will be discussed. How transfer is and was defined continues to influence and shape transfer of learning research and, therefore, it is important to parse out the various definitions and their impact on research outcomes and perceptions. Included in the chapter is a discussion measuring how well students are prepared to apply new science concepts and the identification of concepts being transferred. The context of the research is the middle school science and technology laboratory. Specifically, how the laboratory and scientific inquiry supports student conceptual understanding, the influence of ICT in furthering inquiry-based learning, and teacher awareness of appropriate learning progressions that facilitate conceptual reasoning. A consideration of transfer, the laboratory and inquiry will provide the framework for investigating adolescent conceptions and misconceptions of energy that impact science comprehension and application of new energy concepts to novel situations.
TRANSFER OF LEARNING, A HUNDRED YEAR QUEST

The classical view of transfer is grouped with a researcher-centered perspective and behaviorist view. In this discussion, all three terms are interchangeable. Early 20th century theorists, such as Thorndike (1906), viewed transfer as an all-or-nothing event. It was defined as the appropriate use of prior learning in new contexts (Mestre, 2004). The researcher identified the skills, knowledge, and/or procedures to be transferred. It was the responsibility of the researcher to identify what features from Task A influenced the students’ ability to accomplish Task B, resulting in transfer. Thorndike coined the term *stimulus response and identical elements* as a way to explain the occurrence of transfer. It implies that when moving from task to task a similar mental process could be identified at the cellular level. A well known example from an experiment conducted on college students asked them to answer two separate problems containing similar features. The first problem was:

A general wishes to capture a fortress in the center of a country. There are many roads radiating outward from the fortress. All roads have been mined so that while small groups of men pass over the roads safely, a large force [would have] detonated the mines (Mestre, 2004, p. 4)

The example continues to discuss the full scale attack, how the general divided the troops into small groups to have them simultaneously converge on the fortress. After a few minutes, once the students understood the situation, they where given a follow up problem.

You are a doctor faced with a patient who has a malignant tumor in the stomach. It is impossible to operate on the patient, but unless the tumor is destroyed, the patient will die. There is a kind of ray that may be used to destroy the
tumor. If the ray reaches the tumor all at once and with sufficient high intensity, the tumor will be destroyed, but surrounding tissue may be damaged as well. At lower intensities, the rays are harmless to healthy tissue, but they will not affect the tumor either (Mestre, 2004, p. 4)

The students were asked to describe an appropriate procedure. It was expected that students would apply the underlying concept from the first situation to the second situation. Few were able to solve the procedural problem until they were explicitly told to use the information from the first situation. The lack of evidence for transfer suggested transfer of learning was rare (Mestre, 2004).

Additional arguments against the classical view ensued and many denied the possibility that transfer occurs in situations where stimulus features are not shared (Mestre, 2005). Hoffding (1892), an early 20th century researcher, opposed Thorndike’s (1906) position and suggested that what matters is how the new situation is connected with the thinker’s trace of a previous situation (Lobato, 2006). As research progressed, challenges to the classical view increased. A cognitive view emphasizing the importance of memory, schema activation and mental representation continued to challenge the all-or-nothing approach to transfer.

The cognitive view draws upon an understanding of memory systems including iconic, short-term and long-term memory. Theoretical abstraction of what long-term memory may be, led to an understanding of comprehension, considered a necessary condition for transfer (Mestre, 2005). This view suggests the ability to store and retrieve chunks of information is due to the cognitive development of schemas. Used as powerful
mental representations that contains the same or similar elements useful in transfer. Similarities between the two problems, the shared principle or structure was dependent on how the two problems were mentally represented (Marton, 2006). The goal is to help learners’ identify how one situation may be linked to another, hence, facilitating generalizability, the abstraction of common features between problems and or phenomena. In order for transfer to occur, relevant information from long-term memory needs to be activated and utilized along with the new material being learned (Mestre, 2005). The incorporation of cognition into the transfer discussion spurred emergent views that moved the debate into a new direction. Dynamic transfer, or actor-oriented transfer, and preparation for future learning are aspects of this latest view.

The emergent view has shifted the debate to what transfers as the object of investigation. This must include a better understanding of students’ prior knowledge, their subject knowledge and view of themselves within the classroom setting (Lobato, 2006). In order for learners’ to successfully transfer elements useful in problem solving they must personalize their experiences, creating meaning that resonate with their organizational thinking. The dynamic view of transfer is from the students’ (i.e., actors’) perspective. They are constructing and seeking sameness in problems. In this view, knowledge is activated and applied in response to context (Mestre, 2004). It is a dualistic engagement, involving the learner and phenomena under investigation. It is the process of generalizing features across the problem space. The relations are created by the student, rather than the researcher. All aspects of learning, including student affective, cognitive and physical self,
as well as their environment, teacher, peers, context and content impact the learner’s ability
to generalize between problems. Lobato, among others, utilize clinical interviews along
with scaffolding techniques—supporting student thinking with timely cues and hints—to
facilitate dynamic transfer. Research in the fields of mathematics, physics, and statistics
utilize interviews to facilitate the identification of transfer. Marton (2006) describes the
work of Lobato and Siebert (2002), who conducted a case study among eighth grade
students over a 10 day (3hrs/day) teaching experiment. Interviews were administered on
the first, fifth and final day. The goal was to identify transfer during the process of
interviewing the students. The topic was about measuring the slope of a line as a ratio
between height and length (e.g., the optimal slope of a wheelchair ramp). During the first
interview, the student could not distinguish between the slope and height. By the final
interview the student gained some insight and solved the problem of how to change the
slope of the wheelchair ramp without changing his/her steepness (Marton, 2006). The case
study goes into greater detail, the point being that it was reasonable to point to an event
during the teaching experiment that could possibly be linked to the sudden insight as an
instance of transfer between two situations (Marton, 2006). Another aspect of this
emergent view is students’ preparedness for future learning.

The focus of preparation for future learning (PFL) is how students learn to solve
the problem in the transfer context (Schwartz & Martin, 2004). A key aspect of PFL is the
inclusion of important instructional resources students need to facilitate transfer. This has
led to a double transfer research design paradigm. In this design, half the students from
each group are assigned a separate treatment, given a common resource (e.g., lecture), and assigned a transfer problem. The other half of the students are assigned the transfer problem without the common resource (Schwartz & Martin, 2004). Students’ needed to transfer in what they learned in the instructional treatment into the common resource, then transfer out, what they learned in the common resource, to solve the transfer problem. As a result PFL was able to measure students’ preparation for transfer and the degree to which they transferred their reasoning to solve the novel problem. Not only has transfer of learning research shifted from the researcher’s perspective to the actor’s (i.e., learner’s) but, increasingly, PFL is an important step towards fully understanding the cognitive needs of students to generalize/transfer across problem spaces.

Transfer is no longer defined as the application of knowledge and skill from one situation to a new situation (Mestre, 2005). It is more appropriate to see transfer as the personal construction of relations of similarity across activities. Moving away from the classical view of transfer, as a measure of psychological phenomena, towards seeing transfer as distributed across mental, material, social and cultural planes (Mestre, 2005). Researchers are interested in how learners create sameness and generalize to solve problems. This is a dynamic process involving rich interactions between student, teacher and instructional resource. Some argue for the abandonment of transfer due to its association with the transportation metaphor (Lobato, 2006). This reflects the variety of different transfer definitions resulting over the past century. Some of the common transfer definitions referenced in the literature include near transfer, positive transfer and negative
transfer (Feinstein, 2006). A complete list of transfer definitions including some associated with laboratory inquiry for instance declarative-to-procedural and procedural-to-declarative transfer is available in Appendix A. But as Lobato and others have argued, the dynamic nature of constructing relations involves more than taking elements from a task and applying them to another task, it is about identifying feature similarities among problems that can be used to problem solve. Lastly, an important aspect of understanding dynamic transfer is context or modes of inquiry. This is where student science and technological investigation, and mental strategies involved in scientific reasoning are practiced. To date, there are few studies on transfer that take place in the science classroom or laboratory setting, even though generalizability is used as a goal of scientific inquiry and problem solving (Linn & Songer, 1991; Tiberghien, Jossem & Barojas, 1998). This is why the application of transfer in science and technology in a laboratory context is of interest.

**THE LABORATORY AND INQUIRY**

The natural world is quite uninformative about underlying mechanisms that govern behavior (Eylon & Linn, 1988, p. 257).

The physical laboratory is a space where the inner workings of the natural world are investigated. It is a setting that encourages inquiry, promotes students’ scientific reasoning and discourse, and the development of practical skills including laboratory procedures, and physical and virtual manipulation of ICT apparatus. Another feature of the laboratory setting is student understanding of the complexity and ambiguity of empirical work (Singer, Hilton & Schweingruber, 2006). It is an environment that supports learner
centered behavior, where prior knowledge, intuitive ideas, cultural practices and beliefs can be investigated, dispelled, and/or integrated into the science learning process. It is important to note that in laboratory environments, social processes play critical roles in cognitive development (Singer et al., 2006). Within the context of a student-centered setting such as this, Singer suggests intervention and negotiation with an instructor is essential in helping students make meaning out of laboratory activities. However, the integration of ICT and simulation in laboratory-inquiry settings alters the interactions between teacher, students, and peers.

The simulation, or virtual laboratory, is a structured environment allowing the user to explore and manipulate a rule-based universe. It is a milieu subject to specific assumptions and constraints that represent an analogical representation of some aspect of the natural world (Glynn, Yeany, & Britton, 1991; NRC, 1996). Driven by underlying data structures, simulations provide an alternative means of exploring aspects of the natural world that could not be recreated in a traditional laboratory setting. However, critics of simulation have argued that the conversation between the learner and teacher is muted (Laurillard, 2004). These instructional interactions are minimized or eliminated, reducing the effectiveness of simulation to a series of read and execute procedures. Thus mimicking process driven laboratory set ups does not guarantee conceptual understanding. Laurillard suggest the potential exists for discursive processes between student-student (S-S), student-teacher (S-T), and student-environment (S-E). The interactions between pairs S-S, S-T and S-E are not entirely isolated or dyads, but instead, recorded instances where the majority of
the interaction/communication is between two individuals. In the case of the S-E interactions the recorded instances is when a student is engaged with the software simulation environment and/or physical apparatus. Appendix B contains Laurillard’s conversational framework for a geology simulation. The arrows indicate the direction of the conversation at different moments during the simulation events. The interactions are occurring between teacher-student and student-environment. There are different conversational frameworks depending on the mediation that occurs. The important point is that a discursive process within simulation environments can be rich and explicit. Other critics of simulation suggest learners fail to separate mental actions such as conceptual linkages and inquiry procedures from the facts of an object (Glynn et al., 1991). Whether it is a physical or virtual laboratory, the practice of science is messy, in part because scientific theory, observed phenomena, and many unknowns are investigated and revealed in the process of inquiry.

Classroom laboratory inquiry is a powerful means of developing scientific reasoning. Audet & Jordan (2005) lists different types of inquiry that support scientific reasoning. They include structured inquiry, which utilizes guided worksheets with brief directions; guided inquiry where a challenge activity is given with minimal teacher direction; open inquiry where teacher-led brainstorming and discussion facilitates the inquiry process; and coupled inquiry, where the teacher chooses the question and the students design the experiment. Even though there are a variety of ways to utilize scientific inquiry in the classroom, the individual components and processes are still needed. They
include making observations, posing questions, examining relevant information from a variety of sources, formulating hypothesis, designing investigations, and using tools to gather, analyze, and interpret data (Audet & Jordan, 2005; NRC, 2006). A result of inquiry is communicating findings. Learners are engaged in applying the inquiry model to their conceptual understanding of scientific phenomena across different real-world experiences (White & Frederiksen, 1998). Critics of inquiry suggest success hinges on developmental readiness. It requires time, increased classroom management, and is too often process driven, which does not guarantee content understanding (Audet & Jordan, 2005). This last point leads to another factor which may play a role in student performance: cognitive load.

**COGNITIVE LOAD THEORY**

From cognitive load and working memory research, we know that the amount and functionality of a student’s previous knowledge determines their ability to overview, filter and process information (Winberg & Berg, 2007, p. 1108).

Earlier in the paper some critics argued that the lack of cognitive readiness reduced the learning effectiveness of science laboratory inquiry. Is it the lack of readiness or its accompanying cognitive load that inhibits performance? Winberg and Berg (2007) conducted a cursory search on pre-laboratory instructional strategies and found much of the content focus was on laboratory apparatus, procedures, and safety. Winberg and Berg suggest the focus of pre-laboratory inquiry should be on student structuring of theoretical knowledge of the domain and review of central concepts. The authors also suggest students
are poorly prepared as a result of traditional instructional strategies, reducing student engagement and increasing cognitive load.

The sources of cognitive load are influenced by learning events, intrinsic properties of the task, or as a result of schema construction. The three primary sources of cognitive load are:

- **Intrinsic cognitive load (ICL)**, which is dependent on the degree of interactivity among elements in the task and the familiarity of the content by the learner.
- **Extraneous cognitive load (ECL)**, which is not related to learning or schema construction but, may instead be caused by poorly organized laboratory settings and inadequate instructional format.
- **Germance cognitive load (GCL)**, which is the result of the learner constructing schemata, such as comparing and contrasting new information with existing knowledge (Winberg & Berg, 2007; Sweller, Merrienboer & Paas, 1998).

The relationship of schemas and long-term memory was discussed earlier in the cognitive and emergent view of transfer. From a CLT perspective, it is the students’ ability to effectively construct schemas as a way to circumvent memory limitations, allowing students to allocate more capacity to learning (Winberg & Berg, 2007). CLT is an important consideration whenever students are involved in complex and rich laboratory environments. They are being asked to choose, select and filter information continuously
throughout the learning process. Cognitive load is common in technological learning settings. In fact, technology education environments have much in common with science education laboratory settings.

**SCIENCE, TECHNOLOGY AND COGNITION**

Up until the 1970s technology and science education were on different curricular paths—emphasis on practical knowledge versus abstract knowledge respectively (Cajas, 2001). Since this time leading organizations, including the American Association for the Advancement of Science (AAAS, 1989), the National Science Education Standards (NRC, 1996), the Standards for Technological Literacy (ITEA, 2000), and the United Nation’s Educational, Scientific and Cultural Organization (UNESCO) have advocated tighter coupling between technology and science. De Miranda (2004) suggests several common outcomes including the promotion of scientific and technical literacy, an understanding of science and technology interdependence in the discovery of new knowledge, and a cultivation of the human dimension associated with the scientific and technological enterprise. Science and technology are seen as core knowledge skills important to all citizens.

Science and technology utilize modern instrumentation to extend intellectual capability. Procedural knowledge, including scientific inquiry process and technological problem solving, are cognitive activities that help prepare students for future science, technology, engineering and mathematics (STEM) disciplines. In the middle grades science and technology education promote the concept of active learning, emphasize the
need to make conceptual connections across knowledge domains, and stress student interaction with primary data—whether it is data collection of natural phenomena or data necessary for completing a design problem solving task (Lovedahl, 2001). The National Assessment of Educational Progress (NAEP) continue to highlight student difficulties in applying the facts they know, interpret data, evaluate experimental designs, and the underutilization of specialized scientific and technological knowledge to draw conclusions. These abilities require a closer connection between cognition, science and technology.

The foundation of cognitively-based models hold three elements of learning and instruction common in both science and technology education. First, the learner actively engages the learning process and content. Secondly, the learner is to reflect on and use existing structures of knowledge to guide and further understanding as well as discover new knowledge. Finally, the learner is part of a collaborative classroom setting where interactions—student, teacher and peer—are highly valued (De Miranda, 2000/2004). This suggest learning-in-doing, meaning, students are increasingly involved in the authentic practice of applying science and technology through learning conversations with each other (De Miranda, 2004). The author suggests students are capable of self-regulation and monitoring of cognitive functions such as memory, control of thinking process, and framing questions—all hallmarks of scientific inquiry. These habits of thought encourage a guided practice where the teacher relinquishes control of the activity in favor of the student taking over the major thinking role.
One issue that requires instructional sensitivity is in information or cognitive overload. Petrina (2007) suggests that cognitive processes are distributed across technological environments. The multitude of interactions within the technological environment demands cognitive flexibility to resolve overload. Students are often caught in the mode of the technological primitive response. This implies that while students are learning to design and solve a problem they tend to gravitate towards straightforward procedures and strategies for information retrieval, trouble-shooting, and debugging. In comparison with experts who utilize their knowledge and skills to explore ideas and advance multiple solutions. This constant artifact-mediation of knowledge, language, symbols, tools and procedures requires a malleable thinker. A means of overcoming the apparent disconnect between science and technology concepts is to highlight the common language associated with the respective other. For example, Cajas (2001) describes how technology education students use notions of tension and compression to explain properties of structures when designing their bridge project, while science educators tend to focus on understanding the function of parts of the structure, with little regard for why bridges fail. Several longitudinal studies conducted by Rowell and Gustafson (1998) documented the lack of instructional commitment towards explaining the relationship between gravity, tension, compression and the constraints that affect design. Moving beyond definitions of technology as doing while science is understanding requires continued commitment towards technological and scientific inquiry. It is important to consider the content sequence that best maps to student cognitive demands.
LEARNING PROGRESSIONS

Students in grades 5-8 recognize the difference between evidence and explanation (NRC, 1996). As well, students’ prior knowledge and its incorporation into the inquiry process influence the design of investigations, types of observations, and methods of interpreting phenomena (Audet & Jordan, 2005). Cognitive readiness within the laboratory setting is also dependent on the appropriateness and timeliness of the instructional strategies. Duschl et al. (2007), a proponent of learning progressions, suggests three key characteristics to further student science learning. First, teachers need to know more about how students learn, have a greater awareness of students’ prior knowledge and know their ability to perform various reasoning skills. Secondly, teachers need to initiate the appropriate levels of inquiry to encourage scientific proficiency. Lastly, teachers need to provide conceptual frameworks and models that have broad explanatory power. For example, inquiry on evolutionary theory, or force and motion could foster web-like cognitive growth. Schemas, connections and extension of scientific understanding may lead to new scientific investigations and problem representation. A knowledge domain that lends itself to laboratory and inquiry is the area of thermodynamics.

THERMODYNAMICS

Theoretical statements in school physics (physical science) are not always about the real world but often about abstract entities which behave rather similarly given the right circumstances. The invention of these abstractions often require exceptional leaps in insight and courage. Such genuine leaps of the imagination are not necessarily easy to follow (McClelland, 1989, p. 164).
The lack of understanding of energy concepts among middle grade students is not unique. In fact, heat and temperature create conceptual difficulties starting with its formal introduction in the fourth grade, through high school and beyond (Holt, Rinehart and Winston, 2005). The majority of 4 to 18 year olds have a single concept for heat and temperature. Students use words like heat, cold, and temperature to refer to the same phenomena (Eylon et al., 1988). Thermodynamics, the mechanical action or relation of heat in natural or man-made processes is a fundamentally important knowledge domain, studied across science and engineering disciplines (Linn & Songer, 1991). The educational research in adolescent conceptual understanding of heat and temperature dates back to the 1970s (e.g., McClelland, 1989; Linn & Songer; Tiberghien et al., 1998). Students encounter many naturally occurring problems in thermodynamics, such as conservation of energy, maintenance of body temperature and cooking. Hence, it is a natural fit for students to study heat energy and temperature across a broad range of situations (Linn & Songer, 1991). The cognitive demand on students learning and reasoning energy matters is a challenge. Lab reports, discussion, informal comparisons, integration of understanding, and the creation of mental models are intertwined in science investigation. Cognitive load and schemata is also of importance in this discussion. The challenge is to provide opportunities for students to reason through central concepts and theoretical knowledge within effective instructional strategies that take advantage of ICT settings.

The implementation of ICT to facilitate collaboration, real time data collection, and interpretation of representations continues. The use of ICT in science laboratory inquiry
frees up students to concentrate on integrating ideas, encourages the understanding of graphs by dynamically displaying changes over time, enhances interactive hands-on learning, and encourages an appreciation of scientific measurement—calibration, irregularities, and accuracy (Linn & Songer, 1991). The laboratory, along with ICT, can aide in juxtaposing the factual from the misunderstandings associated with learning energy topics.

Teacher sensitivity to student prior knowledge and misconceptions are important in the study of heat, temperature, and heat capacity. In physics, heat refers to a type of transfer of energy between two systems—for instance, conduction or work. On the other hand, temperature is one of the quantities that characterize the state of a system (Tiberghien et al., 1998). Another non-obvious energy concept is the notion that all objects in prolonged contact with each other reach the same final temperature. For example, Tiberghien documents how students wrongly predict when heating up water, sand, and sugar that only the water gets hot, because students stated “sand cannot heat up”. Finally, two concepts regarding state change are worth noting. First, temperature stability during a change of state is poorly understood. As well, it is difficult for students to accept, that once a change of state has occurred—for instance, from solid to liquid—the new phase behaves normally (Tiberghien et al., 1998). It is easy to understand how misconceptions can creep into student scientific thinking. In order to create good instructional curriculum, awareness and strategies to help students overcome misconceptions are critical. Additional misconceptions among middle and high school students are:
- Heat and temperature are the same or heat constitutes the higher temperature (Eylon & Linn, 1988).
- Heat is above warm (Eylon & Linn, 1988).
- Temperature is a measure of heat or the effect of heat (Tiberghien et al., 1998).
- It is difficult for students to connect temperatures of extreme value since it is difficult to observe in natural or school laboratory setting (Tiberghien et al., 1998).

For the purpose of this study, conduction and insulation are excluded from the discussion. Energy misconceptions are compounded by context and/or situation in which science inquiry is practiced. In energy related research studies, Linn & Songer (1991) state students fail to recognize which information is essential and which is peripheral. Therefore, they treat problems as dissimilar that may in fact be integrated. Linn & Songer (1991) stress the need for students to integrate several problems so as to recognize the relevant features and build models of understanding that incorporate subsequent problems. This last point supports why transfer of learning is important. Student identification of sameness and similarities between features may assist in problem solving/inquiry performance.

**CLOSING REMARKS**

Transfer of learning is not an all-or-nothing event. Instructional interventions that include clinical interviews are an astute and dynamic means of teasing out what students are learning as well as how they utilize their scientific and technological knowledge to
further inquiry and problem solving. Researchers’ theoretical abstraction of memory systems and long-term storage provides insight into how schemas and student representations are created, retrieved, and applied to new learning situations. It is not enough to identify what is transferred; preparing students to problem solve using the acquired knowledge and skills is equally important. It is the student or actor that is central to the transfer discussion. Learning science is dependent on context, a students’ previous knowledge, classroom culture, and their deeply held beliefs, among other things. The incorporation of ICT and powerful simulation environments is also changing the way students interact with the artificial, yet powerful representations of phenomena. The student-teacher discourse in simulation settings can be as rich, if not richer than the traditional laboratory setting (Laurillard, 2004). The laboratory is a dynamic space where inquiry can extend student scientific fluency. Issues of cognitive load will continue to be relevant as problems of complexity increases and the ubiquity of ICT continues. Many educational researchers have advanced the research on middle grade and high school teaching of thermodynamics (Linn & Songer, 1991). Several of the studies are interested in conceptual change and conceptual understanding. Lobato (2006), Bransford & Schwartz (1999), Mestre (2005) have all been instrumental in reshaping the transfer debate, placing the student at the center of the discussion. To date, many transfer studies among high school and college freshman students are in the areas of mathematics and statistics. The current research work in thermodynamics is focused on eighth grade science and above. Little research in transfer, energy science education, the laboratory and inquiry is tailored
to the larger middle grade science community. The aim here is to add to the body of literature on transfer of learning within an inquiry based classroom laboratory setting where ICT along with traditional laboratory equipment mediate part of the student experience. The focus of the research questions are as follows:

1. What is the variability in learning gain scores as a result of the differences in laboratory environments (physical versus simulation)?
2. How does the physical lab environment versus simulation laboratory environment affect preparedness for future learning scores?
3. How does the physical laboratory environment versus a simulation laboratory environment alter students’ transfer of learning scores?
4. How might student-teacher, student-student, and/or student-environment interactions affect students’ scores?
CHAPTER THREE

METHODS

The process of providing secondary experiences is known as pedagogy, insufficient for today’s demanding world and for holistic growth and development. There is a movement afoot to provide primary experiences, simulations, role-play and so on, so that learners experience cognitively, physically and emotionally (Jarvis, 2006, p. 85).

This section provides information on the participants, ethical issues, and the specific institutional initiative that supports the research study. It also offers information on the laboratory learning setting, the physical science apparatus equipment, and the information and communication technology (ICT) used for real time data collection, graphical representations and computer-based laboratory simulations. Finally, detailed procedures on the week long study are provided, starting with a teacher/parent presentation and ending with a transfer of learning experiment. The researcher is the primary teacher for this study and will be assisted by a university science major. The co-teacher was fully trained in the laboratory procedures and appropriate instructional expectations prior to starting the week long energy science program.

PARTICIPANTS

This learning study was supported by an academy: a pre-college middle grades program designed to increase student awareness and enthusiasm for learning science, technology, engineering, and mathematics (STEM). The academy is an integral part of the local universities’ science outreach initiatives. Nearly 350 students from a wide variety of schools (public, private, charter and home-schooled) and North Carolina counties (e.g.,
Wake, Durham, Johnston, Pitt, Nash, Northampton, Alamance, Orange, Wilson, Lenoir, and Wayne) attended this academy. Based on previous science programs held at the academy, 60% of the students are African American, 20% are Caucasian, 15% are Asian or Pacific Islander, and 5% identify themselves as other. Of the students who participated in the summer program 63% of the students were African American, 20% were Caucasian, 8% were Hispanic and 8% identified themselves as other for a total N=35 (Figure 1).

![Figure 1: Summer program participants.](image)

The academy prides itself in reaching a diverse population and encourages students to pursue STEM disciplines through hands-on inquiry learning activities, projects, field trips, and career awareness.

A volunteer sample of North Carolina middle grade students was generated by ongoing recruitment activities (e.g., NCSci teacher listserv, Middle Educators Global Activities (MEGA) listserv, university community listserv, phone calls and emails to middle school science departments). The aim was an equal number of boys and girls of
similar age, ethnic diversity and ability. Prizes were awarded for the top three students. The ranking was based on attendance and learning gains from pretest and posttest scores. There was a $150.00 registration fee covering programmatic and administrative costs. This was part of a year long Saturday morning program, hence, students and parents were accustomed to paying for this summer program.

MATERIALS

The physical science laboratory accommodated up to 20 students. It contained all the necessary safety features to conduct dry and wet laboratory investigations. Appendix C contains a floor plan detailing the laboratory environment. Each workstation supported four students. The laboratory activities are designed around several heat temperature concepts.

- Heat transfer using tubs of water to sense/observe heat flow between hands immersed in different water temperatures.
- Heat capacity, the heat loss and heat gain of different substances, comparing water, metal alloys and alcohol.
- Observation of changes in climate patterns due to environmental variables including heat, wind, and changes in land surfaces using software applets.
- Coastal wind predictions utilizing physical apparatus, temperature probeware, and data collection software.
PHYSICAL APPARATUS

Each workstation was equipped with an Apple™ laptop Powerbook G4 (Max O.S. X version 10, a 1.25 GHz processor and 1 GIG SDR DDRAM), wireless Internet connection, standard Mac software, and USB enabled ports for external devices. Students used Vernier™ temperature probes and Data Logger Pro 3™ software for real time data collection and graphing (Vernier, 2007). Equipment used for the physical set up includes 150/500 ml beakers, test tubes, rubber stoppers with holes, 250 ml graduated cylinders, light stand, rubber hollow tubing, 500 ml flasks, glass tubing, ring stand, 75 watt light bulbs, and a single electric range burner. Other materials included metal beads, sand, water, ice and rulers. The control group will be provided with instruction on how to use the equipment, software interfaces, and data collection techniques. The Physlet simulation laboratory is restricted to the experimental group (Christian & Belloni, 2004).

COMPUTER SIMULATION

Simulations included the NASA Earth Observatory data set, which provided interactive QuickTime animations on Surface Temperature Patterns, Sea Surface Temperature and Vegetation Index, and a standalone QuickTime movie on Earth Energy Balance (NASA, 2007). The interactive animation provided users with the opportunity to manipulate the images using their built in mouse. For easy access, the data simulations will be downloaded from the Internet to laptop hard drives. The simulation lab was a series of web-based applets entitled Physlet Physics, Physics Content Simulated with Java Applets (Christian & Belloni, 2004). The applets were copied onto the laptop hard drive and
accessed via a web browser, typically the Apple™ Safari. The Physlets contained three levels of difficulty, using illustrations designed to demonstrate physical concepts, exploration, tutorials that provided problem solving strategies, and word problems. The chapter on calorimetry provided students with the opportunity to interact with a simulation environment. Instruction on how to use all the equipment and software will be provided to the experimental group. They will have no access to the physical calorimetry lab.

**PROCEDURES**

Parents and students were invited to an open house one week prior to the start of the program. The presentation included a content overview on energy science, program registration, and signing an Informed Consent Form for Research (Appendix D). Students then completed a 20 minute pretest (Appendix E). At the end of the night a “60 Minutes” television segment on climate change was viewed by the audience (Pelley, 2007). This themed based summer program included mathematics and a computing technology class. Lesson plans from the other two classes were shared prior to the start of the program to minimize undue experimental contamination. Hours of participation were from 8:00 a.m.-12:15 p.m. daily, with each group rotating between three 75 minute class periods. The first class period was the practice group, where the instructional delivery is tested and refined. They all received the same treatment as the control group. The control group received the physical laboratory experiment, while the experimental group received the simulation laboratory experiment. All three classrooms were provided with daily inquiry activities, a
common resource, an interactive lecture in the middle of the week, and an identical transfer problem to solve at the end of the week.

**DAILY ACTIVITIES**

**Day 1**

In Part I, laboratory safety protocols were explained. The students were briefed on the purpose and location of the video cameras. They were informed that a different team is to be filmed each day. A brief overview of the topic followed with question and answer time.

In Part II, Sensing Hot and Cold lab, pans were placed in front of the classroom with different water temperatures, warm, lukewarm, and cold. Students placed their left hand in the warm water, right hand in the cold water and, after 15 seconds, placed both hands in the lukewarm water (Figure 2). They were asked to describe their sensations in terms of general feeling and direction of the heat energy, complete a worksheet, and contribute to a class discussion (Appendix F).

![Figure 2: Sensing hot and cold.](image)

In Part III (a), using Vernier™ temperature probes and Logger Pro 3™ interface, students placed the lukewarm water from Part II in a test tube, drew a prediction line in the
Logger Pro 3™, set their intervals, and collected temperature data. This was their practice run, since it was the first time they had used Vernier™ and Logger Pro 3™.

In Part III (b), Equilibrium Experiment, students were provided with the following probing question: *What happens when two fluids of varying temperature come into contact with each other?* Students placed warm water and cold water in two separate test tubes (Figure 3). Drew a prediction line and set up 10 second per sample intervals for 2 minutes. After observing the individual temperatures, students appended a new set of prediction lines reflecting the mixing of the warm and cold water (Figure 4). They set up their intervals at 10 seconds for 4 minutes, collected data samples, and completed a worksheet (Appendix G).

![Figure 3: Equilibrium, comparing heat loss and heat gain.](image1)

![Figure 4: Equilibrium, mixing hot and cold water.](image2)
The final aspect of Day 1 was a hand-out with three thermometers representing Fahrenheit, Celsius and Kelvin. They had to determine \textit{what temperature states are represented at the different intervals for water}. Also, a second sheet with temperature conversion problems was given as homework (Appendix H).

\textbf{Day 2}

The control group (Group 2) conducted the physical calorimetry lab—used to measure the amount of heat produced or lost from a system. Teams launched Logger Pro 3\textsuperscript{TM} and set up 10 second intervals for 10 minutes. Temperature probe 1 was inserted in a Styrofoam\textsuperscript{TM} cup containing 50 ml of an assigned substance either pellets, alcohol, or cold water, while temperature probe 2 was inserted in a Styrofoam\textsuperscript{TM} cup filled with 50 ml of warm water (Figure 5). After 10 minutes they transferred the warm water and temperature probe 1 into their assigned substances until the temperatures level off (Figure 6). They then recorded the statistics and processed the data (Appendix I).

\begin{center}
\includegraphics[width=0.5\textwidth]{figure5.png}
\end{center}

\textbf{Figure 5: Physical calorimetry lab set up.}
The experimental group (Group 3) conducted the Java-based simulation Calorimetry lab using the Physlets software. Each team completed the virtual simulation lab on specific heat, Calorimetry, and a problem set. The temperature change simulation consisted of comparing the time it takes for a substance, that is assigned a specific mass, to gain heat energy on a low heat setting versus a high heat setting. The Calorimetry simulation compares heat absorbed by water and heat released by a solid block immersed in water. For each trial run the mass of the block is changed. The problem set simulation is a series of three simulations whereby the same mass of material starts at the same temperature. The goal was to rank the materials in order of their specific heat capacity. Instructions, worksheets, and data collection tables were provided (Appendix J).

Day 3

In Part I, all three cohorts were given a word problem “brainteaser” to test their understanding of calorimetry and heat capacity. This helped to determine the instructor’s perception of the students’ preparedness to transfer in what they experienced the previous
two days (Appendix K) (Schwartz & Martin, 2004). In Part II, a common resource lecture on *Patterns of Change* included discussions on temperature effects on climate change; temperature change over large scales of time; ocean currents as an energy conveyor belt; and the influence of temperature on air pressure to create wind (Appendix L). Part III, involves virtual QuickTime™ labs, where students interact with a series of animations concerning *Surface temperature patterns*, and *Sea surface and vegetation index* and view a QuickTime™ “Greenhouse effect model” (NASA, 2007)

**Day 4**

All cohorts were given a novel laboratory inquiry to solve. Students were asked to predict wind direction near the coast on a typical sunny day. They were given minimal guidance, the physical apparatus was set up, and Vernier™ probeware and Logger Pro 3™ was available for their use. The physical set up models a sunny day at the beach. A lamp, sand, and water will represent the sun, beach, and ocean respectively. A ruler, beakers, ring stand, and cross bar was also provided (Figure 7). Student predictions were represented in the form of a diagram or illustration with labels (Appendix M).

![Figure 7: Invention lab set up.](image)
Day 5

A posttest administered at the beginning of class (Appendix E), was followed by team presentations and classroom discussion. A closing ceremony with certificates and prizes were given out. Awards for the top finishers were mailed two weeks after the program is completed.

**EXPERIMENTAL DESIGN**

This study is a 2 factor design consisting of 35 students divided into three homogenous groups (Figure 8). The researcher pilot tested the daily activities on Group 1. Group 2 (control) and Group 3 (experimental) was the focus of the statistical analysis.

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Treatment A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical vs Simulation</td>
<td>(Control Group)</td>
</tr>
</tbody>
</table>

| Treatment B | (Experimental Group) |

**Figure 8: Two factor design matrix.**

Student scores to assist in understanding learning gains and transfer of learning success were used to analyze results. Specifically, the difference in pretest and posttest scores, based on a 12 item quiz, was used to measure student learning gains of energy concepts. Secondly, a pencil and paper test was also given in the middle of the week to determine student preparedness for transfer. The objective was to identify students’ ability to *transfer in* what they have learned as a result of the laboratory experiences from Day 1
and Day 2. Finally, scores from the invention lab, given at the end of the week, also assisted in determining the students’ ability to transfer out their common resource and their laboratory experience either the physical or simulation lab set up. To support the statistical findings, extensive video recordings of student-teacher (S-T), student-student (S-S) and student-environment (S-E) interactions were used to qualify how the laboratory environment and changes in it may have contributed to student performance. A matrix was used to capture both the type and frequency of interactions. Specifically, S-T, S-S and S-E interactions associated with apparatus set up, familiarity with software interface, understanding and execution of laboratory procedures, content understanding, interfacing with the equipment, software, data, and troubleshooting, these variations are labeled in Figure 9 as discursive context.

![Figure 9: Laboratory discourse interactions.](image)
The dependent variables include the various student scores—pretest, posttest, midweek transfer in and end-of-week transfer of learning scores. The independent variable is the difference in laboratory set up, the physical versus simulation set up. The control group (Group 2) were provided with physical apparatus set up and instructional guidance to complete the calorimetry lab. The experimental group (Group 3) were provided with the simulation environment and instructional support to complete calorimetry simulation lab.

Nonparametric statistics, as a result of investigating the statistical power of the study, was used. Descriptive statistics were also used to compare pretest and posttest scores, identify differences in learning gains, preparation for transfer, and week ending transfer of learning scores. The comparative results may infer how laboratory experiences influence gains in conceptual understanding of heat, temperature, heat flow, and heat capacity and what was transferred into the novel situation. The Spearman Rank Order statistic will help determine the correlation between the transfer in test and the transfer out test while the Wilcoxon Signed Ranks statistic will rank the number of students who exceeded the pretest score on their posttest, demonstrating learning gains as a result of certain laboratory experiences. Video recording student, teacher and peer discourse interactions will generate frequency statistics and qualitative observations, which may inform connections between learning gains, transfer and classroom activity.

Research validity

Internal validity issues include history, how external events affect the outcome of a research study, this includes student personal history and differentiation in learning
(Campbell & Stanley, 1963). Instrumentation validity is where changes in learning gain as a result of changes in the instrument used to assess pretest and posttest scores alter outcomes. External validity issues include the Hawthorn effect, where participants are aware of their participation in the educational experiment. Self-selection, the students decide whether or not they are going to participate in the study, which makes this a convenient sample. Experimenter effect, the dual role the researcher/instructor may have on student performance. As well as pretest and posttest sensitization affected by administering the exact same test before and after the intervention. Finally, the measurement of dependent variable is the researchers’ concern with the generalizability of the experiment. This is a mixed method study supported by the following research questions:

1. Is there variability in learning gain scores as a result of the differences in laboratory environments (physical versus simulation)?
2. Does the physical lab environment versus simulation laboratory environment affect preparedness for future leaning scores?
3. Does the physical laboratory environment versus a simulation laboratory environment alter students’ transfer of learning scores?
4. How might student-teacher, student-student, and/or student-environment interactions affect students’ scores?
CHAPTER FOUR

RESULTS

NONPARAMETRIC STATISTICS

Group 2 (control) and Group 3 (experimental) mean—pretests, posttest, learning gains, transfer in and transfer out—scores do not reflect normal probability curves (Appendix N). The learning gain mean scores were used to tabulate the Cohen’s $d$ effect size = .127 and significance level $X^2(1) = .3870$ (Figure 10). The combination of small effect size and large significance level does not pose any immediate inferential problems (Kramer & Rosenthal, 1999). Finally, the population sample of $N = 24$ reinforced the decision to use non-parametric statistics since the normality assumptions cannot be confirmed. An alpha of .05 was used to test for any significance.

<table>
<thead>
<tr>
<th>Significance Level (p)</th>
<th>Effect Size (d)</th>
<th>Large</th>
<th>Small</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td></td>
<td>no inferential problem</td>
<td>mistake statistical significance for practical importance</td>
</tr>
<tr>
<td>Large</td>
<td></td>
<td>mistakenly conclude &quot;nothing going on&quot;</td>
<td>no inferential problem</td>
</tr>
</tbody>
</table>

Figure 10: Relationship between Cohen effect size and significance level in determining effect of sample size on the study.
The control group showed a gain from pretest (M=12.17, SD=5.254) to posttest (M=13.17, SD=4.130) as did the treatment group scores (M=10.25, SD=4.555 and M=13.17, SD=3.713, respectively). The control group showed a learning gain of (M=.75, SD=4.330) as did the treatment group score of (M=2.75, SD=3.571, respectively) (Figure 11). Group 2 and Group 3 showed transfer in scores of (M=2.04, SD=.144 and M=1.71, SD=.689, respectively). While Group 2 and Group 3 showed transfer out scores of (M=.965, SD=.965 and M=2.17, SD=1.030, respectively) (Table 1, Figure 12). Spearman’s Rank Order Correlation of (.366 and .398) for the control group and treatment group correspondingly showed a positive linear relationship between the week long laboratory activities and the end-of-week transfer of learning task (Figure 13).

**Table 1: Descriptive Statistics.**

<table>
<thead>
<tr>
<th></th>
<th>Group 2</th>
<th></th>
<th>Group 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard</td>
<td>Mean</td>
<td>Standard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deviation</td>
<td></td>
<td>Deviation</td>
</tr>
<tr>
<td>Pretest (^1)</td>
<td>12.17</td>
<td>5.25</td>
<td>10.25</td>
<td>4.55</td>
</tr>
<tr>
<td>Postest (^1)</td>
<td>13.17</td>
<td>4.13</td>
<td>13.17</td>
<td>3.71</td>
</tr>
<tr>
<td>*Learning Gains</td>
<td>.75</td>
<td>4.33</td>
<td>2.75</td>
<td>3.57</td>
</tr>
<tr>
<td>Transfer in (^2)</td>
<td>2.04</td>
<td>.144</td>
<td>1.71</td>
<td>.689</td>
</tr>
<tr>
<td>Transfer out (^3)</td>
<td>.965</td>
<td>.965</td>
<td>2.17</td>
<td>1.03</td>
</tr>
</tbody>
</table>
Note: Extraneous Variables: Age: $M = 12.39, SD = .65$ Gender: $N$ girls = 16, $N$ boys = 8

*Effect size formula = $M_2 \text{ (post)} - M_1 \text{ (Pre)}$ 
$\frac{(N_1-1) S_1^2 + (n_2-1) S_2^2}{n_1 + n_2 - 2}$

* $X^2(1) \text{ Test of significance} = (\text{effect size})^2 \times N \text{ (size of study)}$ expressed as a p value

1 Pre and post test maximum possible score = 25

2 Transfer in maximum possible score is = 4

3 Transfer out maximum possible score = 7

Figure 11: Learning gain scores.

Figure 12: Transfer scores.
Figure 13: Linear relationship between transfer in score and transfer out score.

Group 2 Wilcoxon Signed Ranks statistic tabulated negative ranks, indicating four individual posttest scores were lower than their pretest scores, and positive ranks indicating seven posttest scores were higher than their pretest scores, with one individual having the identical score on both the pretest and posttest. The Wilcoxon Signed Ranks statistic, converted to a z-score = -.850 with a significance P = .395. Group 3 Wilcoxon Signed Ranks statistic tabulated negative ranks, indicating two individual posttest scores were lower than their pretest scores, with positive ranks indicating nine individual posttest scores were higher than their pretest scores, with one individual having the identical score on both the pretest and posttest. The Wilcoxon Signed Ranks statistic, converted to a z-score = -2.229 with a significance P = .026. Indicating 98.71 percent of the time another self-selected group of N=24 students would score higher on the posttest than the pretest. Group 2 and Group 3 had a greater number of students with positive rank scores on their posttest scores (Figure 14).
STUDENT DISCOURSE INTERACTIONS

The interactions cover student-student (S-S), student-teacher (S-T) and student-environment (S-E). A transcribed list of interactions is available in (Appendix O). In Group 2 S-S and S-T interactions were frequent for content clarification, and interactions between data collection and the physical apparatus. There was a high number of S-T interactions associated with content clarification and a medium number of S-T interactions related to apparatus set up and the Logger Pro interface. There were a medium number of S-E interactions associated with data collection and the apparatus. In many instances only a couple of S-S, S-T and S-E interactions were observed across each type of discourse. There were no interactions observed for content issues or S-T interactions related to laboratory procedures (Figure 15).
### Discourse Interactions

<table>
<thead>
<tr>
<th>Discourse</th>
<th>Interactions</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S-S</td>
<td>S-T</td>
</tr>
<tr>
<td>Apparatus set up</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning the interface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conceptual overview</td>
<td></td>
<td></td>
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<tr>
<td>Conceptual clarification</td>
<td></td>
<td></td>
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<tr>
<td>Apparatus-conceptual content</td>
<td></td>
<td></td>
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<tr>
<td>Interface-data</td>
<td></td>
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<tr>
<td>Troubleshooting equipment</td>
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</table>

**Note**

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency</th>
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</thead>
<tbody>
<tr>
<td>Student and Student (S-S)</td>
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</tr>
<tr>
<td>Student and Teacher (S-T)</td>
<td>Low</td>
</tr>
<tr>
<td>Student and Environment (S-E)</td>
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</tr>
<tr>
<td></td>
<td>High</td>
</tr>
</tbody>
</table>

**Figure 15: Control discourse interaction matrix.**

Note: Each day two teams were video recorded. The color coding corresponds to the number of observations documented each day. White = 0; Hatch ≤ 2; Gray ≤ 4; Black ≥ 5

In Group 3 a high number of S-S and S-T interactions were observed for concept clarification and issues related to the interface and data collection. There were a medium number of S-S interactions associated with data collection and the apparatus, and low number of S-S and S-T interactions observed for the apparatus set up, software interface and laboratory procedure. A low number of S-T interactions were observed between the apparatus and data collection. There were a high number of instances associated with S-E interactions with the interface and data and medium number of interactions associated learning the interface and conceptual clarification (Figure 16).
**Interactions**

<table>
<thead>
<tr>
<th>Discourse</th>
<th>Interactions</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>S-S</td>
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<td>Apparatus set up</td>
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<td>S-T</td>
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<tr>
<td>Learning the interface</td>
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<td>S-E</td>
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<tr>
<td>Laboratory procedures</td>
<td></td>
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<tr>
<td>Conceptual overview</td>
<td></td>
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<tr>
<td>Conceptual clarification</td>
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<td></td>
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<tr>
<td>Apparatus-content</td>
<td></td>
<td></td>
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<tr>
<td>Interface-data</td>
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<tr>
<td>Troubleshooting</td>
<td></td>
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</table>

**Note**

<table>
<thead>
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<th>Type</th>
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<th>Frequency</th>
</tr>
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<tbody>
<tr>
<td>Student and Student (S-S)</td>
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<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
</tr>
</tbody>
</table>

**Figure 16: Experimental discourse interaction matrix.**

Note: Each day two teams were video recorded. The color coding corresponds to the number of observations documented each day. White = 0; Hatch ≤ 2; Gray ≤ 4; Black ≥ 5

**ANALYSIS**

The Group 2 pretest and posttest learning gain score (M=.75, SD=4.33) suggests no significance as a result of the week long activities. The average transfer in score does suggest mild preparedness for the final transfer out task, even though the mean transfer out score was low. This is also corroborated by the Spearman statistic (rho = .366) that suggests a mild positive correlation between the week long activities and the transfer out task. Finally, there were nearly twice as many students who scored higher on the posttest learning gain score than their pretest score. With
p > .05 for the Spearman rho statistic, no evidence of significance was found between the activities leading up to the transfer out task.

In the case of the Group 3 experimental group, the mean learning gain score was three times greater than in the control group. Group 3s transfer in score was smaller than Group 2s in terms of mean difference, which suggest Group 3 was less prepared to succeed in the transfer out task. Yet, their transfer out task was greater than Group 2s score. Once again the Spearman statistic (rho = .398) implies a positive linear correlation between the week along activities and the transfer out task. Finally, greater than fifty percent of the students scored higher on their posttest score than their pretest score. The p < .05 for the Spearman rho statistic suggests some significance between the activities leading up to the transfer out task.

**LEARNING GAIN ANALYSIS**

Group 2 marginal learning gain scores may have been the result of several factors. The use of physical equipment throughout the week competed with the cognitive demands of the students (Petrina, 2007). A continued emphasis on pre-laboratory activities that focused on understanding how the equipment works and procedures may have diverted their attention away from laboratory-specific cognitive tasks and or created some extrinsic cognitive load (Winberg and Berg, 2007; Singer et al., 2006). This is noticeable in several interactions between S-T pertaining to student time needed to navigate the laptop environment during the first couple of days, the need for them to understand laboratory procedures and interface with the logger pro 3™. A specific instance was changing the
sample rate to ensure reasonable data collection and using the software to draw prediction lines. The high number of S-T interactions may suggest students were trying to overcome some overly large germane cognitive load levels (Winberg and Berg, 2007). They often needed assistance in how to interpret the data being captured, which led to many S-T interactions on the relationship between the probes, water temperature and the graphs.

Group 3 had to contend with many of the same cognitive load challenges encountered by Group 2. Similar S-S interactions associated with sharing ideas on possible solutions, discussions on differences in hand temperature during the mini-lab on Day 1, and peer negotiation on how to place the sensors and set up logger pro were common (Winberg and Berg, 2007; De Miranda, 2004). One area of difference was in the S-T and S-S interactions in the simulation environment. Group 2 continued to experience data collection in a linear manner. They had no opportunity to interact with the temperature data in real time once data collection started. Group 3 S-T and S-E interactions provided evidence of students re-running the simulations while discussing heat and temperature concepts (Laurillard, 2004; Linn, 2004). Group 3 students were also engaged in comparing the graphs based on differences in heat capacity of materials and they easily responded to temperature questions while interacting with the simulations (Laurillard, 2004). This notion of learning in doing is supported by De Miranda (2000/2004). In fact, students in Group 3 physically displayed an attempt at re-conceptualizing their understanding as a result of engaging in the simulation environment (Lobato, 2006; Lobato & Siebert, 2002). This hints to a greater comfort level in rationalizing the relationship between the
simulation models and the inner workings of phenomena (Glynn, 1991; NRC, 2006). The mode of inquiry and discourse in the simulation environment was as rich if not richer than with Group 2, who appeared increasingly passive with the laboratory data collection techniques and less communicative during the process (Laurillard, 2004). Group 3’s seemingly richer S-T, S-S and S-E interactions may also suggest some differences in reasoning through inquiries. Increased engagement with the simulation may be a direct result of the laboratory set up and seamless integration of ICT in the activity (Lewis et al., 1993; Linn, 2004). It may have been easier and more natural to engage in real-time with the simulation environment. The fluidity of the various interactions also encouraged greater collaboration.

**TRANSFER IN ANALYSIS**

The difference in Group 2 and Group 3 transfer in scores is marginal. Even though Group 3 interactions with the simulation lab suggest greater engagement, the net result is still similar scores. The change in environment from physical apparatus or simulation to a straight paper pencil test may not have promoted the same level of engagement. Lobato (2006/2002) and Schwartz & Martin (2004) discuss the need for interviewing and dialog during transfer related events. The students’ ability to transfer in teacher-centered expectations is counterintuitive to the dynamic transfer context suggested by Mestre (2004). Closer investigation into the written responses, suggest some near transfer in the use of words and concepts. Group 2 utilized terms such as energy transfer to discuss the interaction between the burner and the material.
Student A–“They both received the same energy but the oil was just hotter because it's thicker than water. For water to heat [up] it takes a long time since it's thin. I think when the molecules in something are closer together it's easier for them to heat up like oil. When the molecules are far apart than the heat can't reach them as fast, like water.”

Several other students suggested the oil may contain more substance, implying either weight change or denser material affected heat gain.

Student B–“The chemicals and the substances in the oil probably made the oil hotter than water.”

Student C–“Because the oil might have more stuff to heat up than the water.”

Student D–“...the oil has more components to make it hotter.”

Another student discussed the difference in material properties between water and oil, while another student discussed “the ability of some materials to hold more heat”.

Student E–“...oil is heavier than water and heated up faster than water.”

Student F–“Waters boiling point is 100C but it doesn't have more of a heat capacity than oil.”

Overall, it was difficult for students in Group 2 to connect some of what they learned to fully solving the word problem. The written results from Group 3 were similar to Group 2. Issues of density, properties of the substances, were mentioned along with several responses that incorporated the terms heat flow and heat capacity.

Student G–“...oil and water probably have different heat capacities, so it would take longer for the water to heat up.”
TRANSFER OUT ANALYSIS

The week ending transfer out responses were also mixed. Both Group 2 and Group 3 provided either diagrams of the apparatus set up or line art depicting their view of a sunny day at the beach (Figures 17 & 18).

Figure 17: Student representation of transfer out apparatus set up.

Figure 18: Student representation of transfer out phenomena.
In Group 2 prior knowledge associated with gravitational pull was suggested. Lobato (2006) suggest prior knowledge is important in understanding what students have transferred. This is in keeping with a student centered view of transfer.

   Student H—“[A]t sunset the moon pulls [the] tide towards the sand which causes the sand to cool because the water is cold.”

   Student I—“...during the day the sun pulls the tide towards water and during night the tide is pulled toward shore.”

As well the term pressure was used to describe a property of a material as opposed to the effect of cold air filling in the vacuum left by the warm air.

   Student J—“The water had cold pressure and the sand has hot pressure. The two pressure[s] crashing into each other will create wind.”

The concept of heat absorption by a particular material and how cold air is attracted to warm air may infer students were trying to develop a relationship between hot air rising and cold air taking its place. Tiberghien (1998) suggest the inability of students to distinguish central differences between, heat, temperature and pressure becomes a road block to further understanding.

   Student K—“In the noon [day] the sand is absorbing more heat than the water. In the night the sand absorbed less heat than the water.”

Group 3 written responses were similar, concepts of pressure differences between hot air and cold air and air capacity were intermixed with the term heat capacity, suggesting students were trying to pull from an earlier concept introduced in Day 2 on heat capacity of materials.
Student L—“There is more air capacity in the sand and therefore it warms faster.”

Several students in Group 2 and Group 3 argued the model used to represent a sunny day at the beach was incorrect.

Student M—“A real model would be different because of the size and texture. The sun and atmosphere would also change affect [sic].”

They were influenced by the smallness of the scale, the color of the sand, and how the light source did not act in the same way as the sun.

Student N—“It might be different because it is a small scale and there need to be more water or some wind.”

Student O—“The beach is different because it has black sand and our "sun" [lightbulb] is not as the real sun.”

Student P—“A real coastline has more people and more land and more water.”

In one S-E interaction a student was trying to feel if in fact there was wind being generated by the model.

Student Q - The way the ocean pushes and pulls and from this picture you can't tell the way the wind...”

Student R —“...the model has no wind.”

This inability to understand the role of models as a representation of natural phenomena was difficult for some students to overcome. The concepts under observation required a leap in insight (McCleland, 1989). Students had difficulty extrapolating the features of the model that were relevant to the transfer out challenge. As Glynn (1991) suggest, there was
a need to discuss the model as an analogy and not as an accurate representation of the beach.

CHAPTER FIVE
CONCLUSION

The use of simulation labs as a replacement and/or add on to classic laboratory set up is promising. The ability for students to conduct multiple trial runs of a laboratory experiment tends to increase their level of engagement and interest. Instructors should continue to interact with students while in simulation environments. Students who worked solely with the apparatus equipment relied on the instructor (using scaffolding techniques) for procedural as well as conceptual knowledge support. While the simulation setting encouraged more time and increased interactions on conceptual aspects of the problem. The monitoring of discursive discourses between the teacher, student and environment is important. Issues of laboratory apparatus, inquiry procedures, science and technology content or data visualization activities require an ongoing dialogue with multiple participants. As the study of thermodynamic concepts continues to be a challenge, further exploration into content progression may provide some insight into possible remedies. Awareness and/or measurement of cognitive readiness should be part of the instructional strategy and planning process (NRC, 1996; Audet et al., 2005; Duschl et al., 2007).

Transfer continues to be an illusive event to measure. The inclination to measure transfer using the transportation metaphor provides a missed opportunity to measure transfer in the context of the learning environment (Lobato, 2006). Just looking at transfer of learning
scores is not enough, various forms of documentation and interactions (e.g., scaffolding) are needed to draw out student reasoning (Linn et al., 2004). Finally, students need additional opportunities to interact with models and other forms of representation that inform understanding of natural phenomena. As with thermodynamic concepts, the invisible is difficult to visualize and represent conceptual challenges among middle school students. The dualistic nature of physical/simulation laboratory environments while learning science concepts suggest the need for continued opportunities for peer collaboration and discourse with knowledgeable instructors (Singer et al., 2006). Forms of inquiry and problem solving along with intuitive ICT environments will continue to encourage a dynamic construction of knowledge among students (Linn & Songer, 1991). The practice of incorporating science and technology pedagogy to further scientific and technological reasoning will continue to be of critical importance in the 21st century.

There are several limitations to this study. Their was an attempt to identify general learning gains and transfer gains, and student instances of reasoning and communication through discourse analysis, but there is a need to consider instructional strategies that incorporate clinical interviews and performance measurements that identify student meaning-making in science. Measuring student transfer and learning gains require additional time that was unavailable for this study. Future research should consider longitudinal studies to deepen our understanding of ‘what’ is transferred. The concepts covered in the laboratory set-ups, simulations versus physical apparatus, were similar, but more detail is needed to map the concepts from both settings to measure the benefits in
working in different mediated environments. Even though every attempt was made to map
the energy science content to student grade learning progressions, differences in student
school experiences both academically and socially, may have negatively impacted their
performance in the week long program. More research is needed in mapping science
content to student cognitive ability. The small \( N \) makes it difficult to generalize this study
over a larger population. A larger sample size over a longer period of time is needed to
further validate the findings of this study. Transfer of learning in science continues to be a
suggested goal among researchers. Transfer is equally discussed in other STEM disciplines
such as engineering design and technology education. Sub-disciplines including
engineering design graphics continue to provide research on student ability to manipulate
spatially, as a predictor of success in engineering. There are opportunities to leverage the
research literature in transfer and engineering graphics to transfer in science and other
STEM disciplines.
REFERENCES
American Association for the Advancement of Science (AAAS) (1989). *Science for all Americans: A project 2061 report on literacy goals in science, mathematics, and technology*. USA: AAAS.


APPENDIX A

TRANSFER OF LEARNING DEFINITIONS
## Appendix A

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near transfer</td>
<td>Similarities between situations of original learning and the conditions involved in transfer e.g., classroom activities.</td>
</tr>
<tr>
<td>Far or High Road</td>
<td>Little similarity between the two events e.g., classroom activity versus an out of school activity.</td>
</tr>
<tr>
<td>Low road transfer</td>
<td>Depends on extensive and varied practice of a skill to near automaticity (Perkins &amp; Solomon, 1989).</td>
</tr>
<tr>
<td>Literal transfer</td>
<td>Using knowledge or procedure directly towards a new learning event (Bransford and Schwartz., 1999; Haskell, 2001).</td>
</tr>
<tr>
<td>Figural transfer</td>
<td>The application of a piece of world knowledge e.g., the use of metaphors, similes or analogies to a novel situation</td>
</tr>
<tr>
<td>Positive transfer</td>
<td>The application of knowledge to a new problem resulting in new and strengthened learning (Feinstein, 2006).</td>
</tr>
<tr>
<td>Negative transfer</td>
<td>The interference of new learning, considered a short-term condition that can be corrected with appropriate feedback (Feinstein, 2006).</td>
</tr>
<tr>
<td>Content-to-content transfer</td>
<td>Is making use of what we know in one subject area to the learning in another subject area (Haskell).</td>
</tr>
<tr>
<td>Skill-to-skill transfer</td>
<td>Is using the procedures in one skill area into another skill area (Haskell).</td>
</tr>
<tr>
<td>Declarative-to-procedural</td>
<td>Is learning about something helps in actually doing something. The unintended consequences of learning that benefit another task (Haskell).</td>
</tr>
<tr>
<td>Procedural-to-declarative</td>
<td>Is when practical experience helps us learn more abstract knowledge in another area (Haskell).</td>
</tr>
<tr>
<td>Strategic transfer</td>
<td>Is knowledge of how we solved one problem may help in solving another problem (Haskell).</td>
</tr>
<tr>
<td>Conditional transfer</td>
<td>Is knowledge concerning ‘when’ to apply the knowledge learned in one context for transfer into another context (Haskell).</td>
</tr>
<tr>
<td>Theoretical transfer</td>
<td>Is deep level relationships of cause in one area that can be transferred in another area (Haskell).</td>
</tr>
<tr>
<td>General transfer</td>
<td>Is when non-specific knowledge transfers to another situation (Haskell).</td>
</tr>
<tr>
<td>Vertical transfer</td>
<td>Is when prior learning transfers to new learning that is higher in knowledge hierarchy (Haskell).</td>
</tr>
<tr>
<td>Lateral transfer</td>
<td>Is when previous learning is transferred to the same level in a hierarchy (Haskell).</td>
</tr>
</tbody>
</table>
APPENDIX B

CONVERSATIONAL FRAMEWORK

This discourse occurs between student-teacher, student-student and student-environment during a science simulation activity.
Conversational framework of a geological simulation (Laurillard, 2004).
APPENDIX C

INFORMED CONSENT FORM FOR RESEARCH
Appendix C

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Teaching heat, energy and temperature concepts to middle grade science students: Measuring learning gains while preparing students for future learning

Principal Investigator: John C. Bedward

We are asking you to participate in a research study. The purpose of this study is to measure transfer of learning gains of middle grade students engaged in learning thermodynamic concepts related to heat, energy and temperature.

INFORMATION
If you agree to participate in this study, you will be asked to:

- Complete a pretest in order to create three equal ability groups of students and compare transfer/learning gains acquired at the end of the five day session.
- Sign a behavior contract
- Laboratory safety will be covered on the first day of the program
- Day 1: all groups will cover a basic thermodynamic lab, incorporating laboratory equipment, information and communication technology. Duration 75 minutes
- Day 2: Two groups will conduct virtual laboratory environments while one group conducts a physical simulation laboratory
- Day 3: All groups cover a set of common resources in physical and virtual environment. Duration 75 minutes.
- Day 4: All groups utilize acquired knowledge skills to problem solve a novel experience. Duration 75 minutes.
- Day 5: Present findings to the class and be video recorded. Each group (3x) will present for a maximum for five minutes. The instructor will utilize guided questions to direct the discussion. Duration 20-40 minutes.
- Day 5: Complete a posttest instrument needed to measure transfer/learning gains. Duration 20 minutes
- The study will take five 75 minute session over a five day period.

RISKS
Different fluids will be used to compare thermodynamic principles, hot water will always be handled by the instructor and goggles are mandatory whenever laboratory activities are taking place. Lab safety protocol will be presented and discussed on the first day of the session with signage posted in the laboratory. All containers will be appropriately labeled.

BENEFITS
Students will gain a better conceptual understanding of the differences between heat, temperature, thermal flow and greenhouse effect. They will develop appropriate laboratory protocols necessary for high school science laboratory settings. Content knowledge and laboratory processes and procedures will reinforce knowledge skills they will use while still in middle school. Student test data gathered from the instructional
intervention will further future research in transfer of learning, integration of information and communication technology, laboratory science learning and appropriate learning progressions for middle school science education.

CONFIDENTIALITY
The information in the study records will be kept strictly confidential. Data will be stored securely in a password protected computer only accessible by the principal investigator. All hard copies will be kept in a locked cabinet. No reference will be made in oral or written reports which could link you to the study.

COMPENSATION (if applicable)
For participating in this study the top student will receive a $100 gift certificate to amazon.com. If you withdraw from the study prior to its completion, you will not be eligible for the $100 gift certificate.

EMERGENCY MEDICAL TREATMENT (if applicable)
All science labs will be conducted in a vented environment with eye wash stations in case of emergency. All emergencies are handled as priority one. Emergency services in the form of campus security and ambulatory service are available through local 911 emergency dispatcher. Parent or guardian will be notified immediately and given proper information on status of their son or daughter.

CONTACT
If you have questions at any time about the study or the procedures, you may contact the researcher, John Bedward, at 2519 Crestline Ave, Raleigh NC 27603 or 919.779.4104. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. David Kaber, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/515-3086) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148)

PARTICIPATION
Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.

CONSENT
“I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time.”

Subject's signature_______________________________________Date _________________

Investigator's signature__________________________________Date _________________
APPENDIX D

LABORATORY FLOOR PLAN
Physical science laboratory floor plan.
APPENDIX E

PRETEST AND POSTTEST ITEMS

Twelve items are administered one week prior to the energy science program and on the last day to assist in measuring learning gains.
Appendix E

Thermodynamics Pretest

Name: ___________________________ Date: ___________ Group: __________

Short answer

Describe in a brief sentence what is energy? _______________________________________

___________________________________________________ _______________________

Multiple choice

_____ 1. What is the state of water at 0°F?
   a) Hot water
   b) Cold water
   c) Ice
   d) Gas

_____ 2. Two square blocks of steel are side by side. Block A weights 50 grams, while Block B weights 200 grams. They each have an initial temperature of 80°F. Which block contains the greater heat capacity?
   a) Block A
   b) Block B
   c) Both Block A and Block B

_____ 3. What is the status of water at 0°C?
   a) Warm water
   b) Cool water
   c) Both a liquid and a solid
   d) Ice

_____ 4. As air gets hot, the air ___________ and __________
   a) Expands, sinks
   c) Contracts, rises
   d) Expands, rises
   e) Contracts, sinks

_____ 5. When energy is transformed, the amount of usable energy
   a) Decreases
   b) Remains constant
   c) Increases
   d) None of the above

_____ 6. As the kinetic energy of the molecules in a substance increases, the
   a) Temperature of a substance increases
   b) Temperature of the substance decreases
   c) Potential energy of the substance changes
   d) Temperature remains the same
Problem Set

If $12 - 3p = -48 + 9p$, what is the value of $p$?

a) 5
b) 17
c) 28
d) 60

Show your work here:

A wooden chair and a metal chair have been in Mr. K's class for twelve hours. The metal chair feels colder when you sit on it than the wooden chair, but when you measure the temperature of the chairs you find that they are both 23°C.

a. Do you think that your temperature probe is working properly?

(circle one) Yes No

b. What is the main reason the objects feel different?

Interpreting Graphs

The figure below shows a thermometer in each of the two graduated cylinders holding water. Use the figure below to answer the questions that follow.

1. Which graduated cylinder contains more water?
   a) The cylinder on the left contains more.
   b) The cylinder on the right contains more.
   c) The cylinders contain equal amounts.
   d) There is not enough information to determine the answer.

2. If the two cylinders are touching each other, what will happen to the thermal energy in the cylinders?
   a) It will pass from the left cylinder to the right cylinder
   b) It will pass from the right cylinder to the left cylinder
   c) It will pass equally between the two cylinders.
   d) Nothing will happen.

If the water in the graduated cylinders is mixed together, which of the following will most likely be the temperature of the mixture?

a) 25°C
b) 35°C
c) 50°C
d) 70°C

Note: Adapted from Dobson, Holman, & Roberts (2004) and Holt, Rinehart and Winston (2005)
APPENDIX F

HEAT FLOW

Students are introduced to the laboratory setting through a mini experiment where they explore heat flow and temperature equilibrium.
Mini-lab 1.A: Sensing hot and cold

Place one hand in the hot water and the other hand in the cold water. Leave them in for 15 s. Then place both hands in the middle container. Answer the following:

<p>| How does the water feel to each hand? |</p>
<table>
<thead>
<tr>
<th>Left</th>
<th>Middle</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| Describe in what direction the heat flows for each hand? |</p>
<table>
<thead>
<tr>
<th>Left</th>
<th>Middle</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| Predict the temperature for each container? |</p>
<table>
<thead>
<tr>
<th>Left</th>
<th>Middle</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Does the volume of water make a difference in how hot or cold water feels? Explain

________________________

________________________

________________________

Note: Adapted from Dobson, Holman, & Roberts (2004).
APPENDIX G

TEMPERATURE EQUILIBRIUM LAB
Appendix G

Lab 1.B: Equilibrium

Date ____________________ Time ____________________

Team Members (2x):

<table>
<thead>
<tr>
<th>(last)</th>
<th>Partner</th>
</tr>
</thead>
</table>

Description:
We often confuse the terms heat and temperature. They are closely related, but in many ways
distinct terms with specific meaning. Today's lab will introduce you to some of the properties of
energy, specifically thermal heat flow—direction, rate of flow, temperature change, heat loss and
heat gain.

What happens when two fluids of varying temperature come into contact with each other?

Objectives/Purpose:
1. Operating sensors, data collection software and measuring temperature
2. Compare heat lost by cooling water and heat gained by warm water

Materials:

![Diagram of lab setup with equipment: Flask, Test Tube, Hot Water, Cold Water, and a graph showing temperature vs. time.]

Procedures:
1. Using the water from the pans place the hottest water in the test tube 2/3 full
2. Place the coldest water in the flask, 1/2 full
3. Launch logger pro software. One table with two columns should appear. One column for
temperature sensor 1 and one column for T° sensor 2
4. Under the analyze menu use the draw prediction tool to estimate the temperature of each
body of water
5. Click [Clock] to set up data collection rate at 10 seconds per sample for 5 minutes
6. Click [Collect] to gather individual baseline samples for 50 seconds
7. Place the test tube in the beaker and collect samples for the remaining 4 minutes.
8. Save file [lastname_lab0] as per instructors directions. Check to make sure the file is
saved in the proper folder

Equilibrium Lab

Energy Science, Climate Change

Note: Adapted from Vernier (2007)
Processing...

Sketch and label final lab set up using basic geometric shapes

Up for discussion....
What was the final temperature of the combined substances?

Which direction did the heat flow?

What is occurring at the molecular level?

Which fluid is losing heat and which fluid is gaining heat energy? Why?

Note: Adapted from Vernier (2007)
APPENDIX H

TEMPERATURE UNITS AND CONVERSION

Students are given homework on temperature units and a practice worksheet on temperature conversions.
Appendix H

Note: Adapted from Dobson, Holman, & Roberts (2004)
Temperature conversions

- Convert 50 °C to °F
  °C → °F
  °F = (1.8 x °C) + 32

- Convert 40 °F to °C
  °F → °C
  Hint: solve for the unknown

- Convert 40 K to °C
  °C → K
  K = °C + 273.15
APPENDIX I

PHYSICAL CALORIMETRY LAB

The control group receives the physical calorimetry lab.
Appendix I

Lab 2: Calorimetry

Date ____________________________ Time ____________________________

Team Members (2x): ____________________________ ____________________________

Objectives/Purpose:
1. Determine heat lost by cooling substance
2. Determine heat gained by warming fluid

\[ Q = mc (T_f - T_i) \]

Materials
Vernier computer interface; Logger Pro; 2 Vernier Probes; graduated cylinder; Styrofoam cup; beaker; water, alcohol, copper pellets, popsicle sticks

Procedures
1. Launch logger pro. Save file to personal folder. Set intervals 10 per minute for 10 minutes.
2. Use a graduated cylinder to get 50.0 mL of either the (cold water, copper pellets or alcohol) from the container supplied by the teacher. Pour the substance into the Styrofoam cup and insert Probe 1.
3. Use a graduated cylinder to get 50.0 mL of warm water from the container supplied by the teacher. Place Probe 2 into the warm water.
4. Measuring temperatures with the computer:
   - Click [collect] to begin data collection. Run collection for 1 minute.
   - While still running the collection transfer the warm water and its probe to the Styrofoam cup.
   - Stir the mixture.
   - Continue collecting data until both temperatures stop changing (level off), then click [stop].
5. Click the Statistics button, [stat]. Record the minimum and maximum temperatures below.
6. Process data

Data

<table>
<thead>
<tr>
<th>Warm Water (Probe 2)</th>
<th>Metal Pellets (Probe 1)</th>
<th>Alcohol (Probe 1)</th>
<th>Cold Water (Probe 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. __________ °C</td>
<td>Min. __________ °C</td>
<td>Min. __________ °C</td>
<td>Min. __________ °C</td>
</tr>
<tr>
<td>Max. __________ °C</td>
<td>Max. __________ °C</td>
<td>Max. __________ °C</td>
<td>Max. __________ °C</td>
</tr>
</tbody>
</table>

Note: Adapted from Vernier (2007)
Processing data

1. Calculate the temperature change, $T_{\text{final}} - T_{\text{initial}}$, for the warming of cold water and the cooling of warm water by subtracting the maximum temperature from the minimum temperature for each process ($\Delta T = T_{\text{max}} - T_{\text{min}}$).

<table>
<thead>
<tr>
<th>Warm water</th>
<th>Cold Water</th>
<th>Alcohol</th>
<th>Pellets</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Calculate the heat gained by the [substance] (in J).
   
   \[ Q = mc (T_f - T_i) \]

3. Calculate the heat lost by the warm water (in J).
   
   \[ Q = mc (T_f - T_i) \]

Note: Adapted from Vernier (2007)
APPENDIX J

SIMULATION CALORIMETRY LAB (PHYSLETS)

The simulation is only administered to the experimental group.
Lab 2: Virtual Calorimetry

Objectives/Purpose:
1. Determine heat lost by cooling substance
2. Determine heat gained by warming fluid

\[ Q = mc (T_f - T_i) \]

Procedures
1. Double click on Physlet folder located on your desktop
2. Click start file
3. Complete Illustration 18.1 – Specific Heat Capacity
   Ignore the text and complete the table provided
4. Complete Illustration 18.3 – Calorimetry
   Ignore the text and complete the table provided
5. Complete Problem 18.7 – Calorimetry
   Ignore the text and complete the table provided

Complete worksheet

Calorimetry lab
Data collection

Illustration 19.1 – Specific Heat

<table>
<thead>
<tr>
<th>kg</th>
<th>Low Heat</th>
<th>High Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>°C</td>
<td>°C</td>
</tr>
<tr>
<td>3</td>
<td>°C</td>
<td>°C</td>
</tr>
<tr>
<td>5</td>
<td>°C</td>
<td>°C</td>
</tr>
</tbody>
</table>

Exploration 19.3 – Calorimetry

<table>
<thead>
<tr>
<th>Weight (kg)</th>
<th>Temperature Block (°C)</th>
<th>Temperature Water (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Final</td>
</tr>
<tr>
<td>1</td>
<td>600</td>
<td>300</td>
</tr>
<tr>
<td>1</td>
<td>800</td>
<td>300</td>
</tr>
<tr>
<td>3</td>
<td>600</td>
<td>300</td>
</tr>
<tr>
<td>3</td>
<td>800</td>
<td>300</td>
</tr>
</tbody>
</table>

Problem 19.7 –

<table>
<thead>
<tr>
<th>Animation</th>
<th>Rank specific heat from smallest to largest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Note: Adapted from Christian & Belloni (2004)
Calorimetry Worksheet

Illustration 19.1 – Specific Heat

State a general principle that explains the difference in temperature change.

Illustration 19.3 – Calorimetry

For a 3-kg block and an initial block temperature of 800 K, use the equation 
\[ Q = mc(T_f - T_i) \] 
to calculate the heat absorbed by the water and the heat released by the copper block when they reach the final temperature.

<table>
<thead>
<tr>
<th>Water</th>
<th>Copper</th>
</tr>
</thead>
</table>

Problem 19.7 –

From your specific heat table list 3 substances that reflect your findings.
# Table 1: Specific heat

<table>
<thead>
<tr>
<th>Substance</th>
<th>Specific heat at 25°C in J/kg°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (Liquid)</td>
<td>4186</td>
</tr>
<tr>
<td>Steam</td>
<td>2093</td>
</tr>
<tr>
<td>Ammonia (gas)</td>
<td>2060</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>2430</td>
</tr>
<tr>
<td>Aluminum</td>
<td>897</td>
</tr>
<tr>
<td>Carbon graphite</td>
<td>709</td>
</tr>
<tr>
<td>Copper</td>
<td>385</td>
</tr>
<tr>
<td>Gold</td>
<td>129</td>
</tr>
<tr>
<td>Iron</td>
<td>449</td>
</tr>
<tr>
<td>Mercury</td>
<td>140</td>
</tr>
<tr>
<td>Lead</td>
<td>129</td>
</tr>
<tr>
<td>Silver</td>
<td>234</td>
</tr>
<tr>
<td>Ice</td>
<td>93</td>
</tr>
</tbody>
</table>
APPENDIX K

HEAT CAPACITY BRAINTEASER

Students are given a problem to solve. This ‘test’ is helping measure preparedness for future learning activity.
Lawrence is making doughnuts and bagels for his friends Jeff and Ellen. He heats one kilogram of oil and water so he can fry the doughnuts and boil the bagels. The oil and water start at room temperature and are heated in identical pots which are on identical burners set at “high.”

Lawrence measures the temperatures to make sure his snacks turn out OK. After five minutes the oil reaches 90° C and the water reaches 70° C.

Jeff thinks that the oil is hotter because it has gained more heat energy than the water. Ellen disagrees saying that about the same heat energy went into both the oil and the water.

Do you agree with Jeff, Ellen, or neither? Explain so Lawrence can understand it!

________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________

Note: Adapted from Linn & His (2000)
APPENDIX L

COMMON RESOURCES LECTURE

All cohorts receive the same information and a set of mini labs exploring the effects of temperature change on the environment and vise versa.
Appendix L

Lab 3: Patterns of change

Date ____________________  Time ____________________

Team Members (2x): ____________________  ____________________

What impact does temperature have on climate shifts?

Notes

Note: Adapted from NASA Earth Observatory (2007)
Lab 1: Surface temperature patterns

Surface patterns of the earth in January and June 1990.

You can view the Earth from the unique perspective of outer space. You will examine monthly snapshots of our planet’s surface and atmosphere. During this activity, you will investigate the seasonal change in the Earth’s surface temperature by looking for patterns and changes over time.

Background: By precisely measuring the radiant energy emitted from Earth’s surface, satellites can determine temperature at the surface-atmosphere boundary. Surface temperature influences the rate at which water evaporates, as well as wind and precipitation patterns and the formation of clouds.

Compare and contrast surface temperature patterns of the two spheres. (List some general observations.)

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

Why do surface temperatures at the equator remain relatively constant, while surface temperatures of the two hemispheres change?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

Note: Adapted from NASA Earth Observatory (2007)
Lab 2: Sea surface and vegetation index

Comparing Sea Surface Temperature to Vegetation Index (Jan 1982–Dec 1998)

During this activity, you will investigate complex interactions of the Earth's lands, oceans, atmosphere, and life by looking for patterns and changes over time in the sea surface temperature and vegetation productivity.

Background: Sea surface temperature data are used to help us predict weather patterns, to track ocean currents, and to monitor El Niño and La Niña. Sea surface temperature influences the growth of phytoplankton, as well as precipitation patterns across continents, thus indirectly influencing land vegetation as well.

A value of zero means no green vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves.

In the animation, how can you recognize El Niño and La Niña years?

Focus on the Amazon. What pattern of vegetation anomalies and sea surface temperature do you observe over time?

Along the equator, winds generally blow from the east to the west. How do the winds and sea surface temperatures affect the vegetation in the Amazon?

Note: Adapted from NASA Earth Observatory (2007)
Greenhouse Effect Model

- How do carbon dioxide and water vapor prevent long wave radiation emitted by the surface of the Earth from escaping to space?

- If all the molecules of carbon dioxide and water vapor were removed from the atmosphere, what do you think would happen to Earth's surface temperature? Why?

- If more molecules of carbon dioxide were added to the atmosphere, what do you think would happen to Earth's surface temperature? Why?
APPENDIX M

INVENTION LAB (TRANSFER OUT)

All cohorts are asked to predict wind patterns on a sunny day at the beach. Appropriate information and equipment is provided.
Appendix M

Invention Lab: Predicting Coastal Winds

Date ____________________________ Time ____________________________

Team Members (3x): ________________________________________________
_________________________ (partner) ________________________________
_________________________ (partner) ________________________________

Introduction
When sailing a boat, you must be able to predict and take full advantage of the wind. A potentially dangerous situation may result if you lose control of the sail boat close to shore when the wind is blowing toward the shore. In many coastal areas, the wind blows toward and away from the shore in predictable ways throughout the day. You must predict which way the wind is likely to be blowing on a typical sunny day.

Objectives/Purpose:
1. Predict which way the wind is likely to be blowing near the coast on a typical sunny day

Feel free to use your notes

Materials: Clip on lamp, 75 watt bulb, 75 ml water, 75 ml sand, ring stand, large rod, temperature probes, ruler, laptop, graphing software, grid paper, beakers

Deliverables
Completed reflection sheet
Hardcopy/softcopy of all documentation.

Note: Adapted from Dobson, Holman, & Roberts (2004)
Reflection...

Once you complete your experiment utilize concepts from the built model to sketch the direction of air that creates a land breeze during noon day sun and direction of air movement after sunset. Add arrows and labels where appropriate. Explain your reasoning.

Do you think your model of a coast is realistic? How might a real coastline differ from your model?
APPENDIX N

HISTOGRAM DISTRIBUTION

Justification for use of nonparametric test partially based on inability to confirm normal distribution
Appendix N

Histogram Distribution of Group 2 Pretest Scores.

Histogram Distribution of Group 2 Posttest Scores.
Histogram Distribution of Group 2 Learning Gain Scores.

Histogram Distribution of Group 2 Transfer In Scores.
Histogram Distribution of Group 2 Transfer Out scores.

Histogram Distribution for Group 3 Pretest scores.
Histogram Distribution for Group 3 Postest scores.

Histogram Distribution for Group 3 Learning Gain scores.
Histogram Distribution for Group 3 Transfer In scores.

Histogram Distribution for Group 3 Transfer Out scores.
APPENDIX O

SPEARMAN RANK ORDER CORRELATION
## Appendix O

### Table 3: Spearman’s Rank Order Correlation (Group 2)

<table>
<thead>
<tr>
<th>Spearman's rho In Transfer Score</th>
<th>Correlation Coefficient</th>
<th>In Transfer Score</th>
<th>Out transfer Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out transfer Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Correlation Coefficient</td>
<td>.398</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.200</td>
<td>.</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

### Table 4: Spearman’s Rank Order Correlation (Group 3)

<table>
<thead>
<tr>
<th>Spearman's rho In Transfer Score</th>
<th>Correlation Coefficient</th>
<th>In Transfer Score</th>
<th>Out transfer Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out transfer Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Correlation Coefficient</td>
<td>.366</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.242</td>
<td>.</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>
APPENDIX P

WILCOXON SIGNED RANK TEST
### Table 5: Wilcoxon Signed Ranks Test (Group 2)

<table>
<thead>
<tr>
<th>Ranks</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posttest Score - Pretest Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative Ranks</td>
<td>4ã</td>
<td>5.88</td>
<td>23.50</td>
</tr>
<tr>
<td>Positive Ranks</td>
<td>7b</td>
<td>6.07</td>
<td>42.50</td>
</tr>
<tr>
<td>Ties</td>
<td>1c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- a. Posttest Score < Pretest Score
- b. Posttest Score > Pretest Score
- c. Posttest Score = Pretest Score

#### Test Statistics

<table>
<thead>
<tr>
<th>Posttest Score - Pretest Score</th>
<th>Z</th>
<th>Asymp. Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-.850ã</td>
<td>.395</td>
</tr>
</tbody>
</table>

- a. Based on negative ranks.
- b. Wilcoxon Signed Ranks Test

### Table 6: Wilcoxon Signed Ranks Test (Group 3)

<table>
<thead>
<tr>
<th>Ranks</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posttest Score - Pretest Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative Ranks</td>
<td>2ã</td>
<td>4.00</td>
<td>8.00</td>
</tr>
<tr>
<td>Positive Ranks</td>
<td>9b</td>
<td>6.44</td>
<td>58.00</td>
</tr>
<tr>
<td>Ties</td>
<td>1c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- a. Posttest Score < Pretest Score
- b. Posttest Score > Pretest Score
- c. Posttest Score = Pretest Score

#### Test Statistics

<table>
<thead>
<tr>
<th>Posttest Score - Pretest Score</th>
<th>Z</th>
<th>Asymp. Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-2.229ã</td>
<td>.026</td>
</tr>
</tbody>
</table>

- a. Based on negative ranks.
- b. Wilcoxon Signed Ranks Test
APPENDIX Q

TRANSCRIBED INTERACTIONS
## Appendix Q

<table>
<thead>
<tr>
<th>Filename</th>
<th>Start Time</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1G1FC PreEqui</td>
<td>00:01:22</td>
<td>S-T needed help getting started w/ laptop</td>
</tr>
<tr>
<td></td>
<td>00:00:49</td>
<td>S-S logger pro set up</td>
</tr>
<tr>
<td>D1G1FBirdBath</td>
<td>00:00:44</td>
<td>S-S hand immersion in bath comparing hand temperature. Placed hands over each other. Attempt to warm up each others hands.</td>
</tr>
<tr>
<td></td>
<td>00:01:59</td>
<td>S compare and contrast hand temperature to temperature on body part (face)</td>
</tr>
<tr>
<td>D1G1RCPT1</td>
<td>00:00:15</td>
<td>Pre-lab T-S whole class discussion on safety, lab protocol and mini-lab (sensing hot and cold water) discussion and experiment</td>
</tr>
<tr>
<td>D1G1RCPT2</td>
<td>00:03:19</td>
<td>Equilibrium lab (part 2) S-T whole class navigating the laptop, creating folders, how to use the mouse</td>
</tr>
<tr>
<td></td>
<td>00:10:03</td>
<td>S-T launching logger pro</td>
</tr>
<tr>
<td></td>
<td>00:13:23</td>
<td>S-E Navigating logger pro software</td>
</tr>
<tr>
<td>D1G1RC PT3</td>
<td>00:01:00</td>
<td>S-T whole class explanation of Vernier probeware and interface</td>
</tr>
<tr>
<td></td>
<td>00:06:50</td>
<td>S-T apparatus set up</td>
</tr>
<tr>
<td></td>
<td>00:10:54</td>
<td>S-T data collection</td>
</tr>
<tr>
<td></td>
<td>00:13:36</td>
<td>S-S data observation comparing what is happening w/ the water in the physical apparatus</td>
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<tr>
<td>D1G1RC PT4</td>
<td>00:02:01</td>
<td>S-S drawing prediction lines, trying to approximate the temperature</td>
</tr>
<tr>
<td></td>
<td>00:03:36</td>
<td>S-T determining units for temperature Fahrenheit or Celsius comparing data table to graph</td>
</tr>
<tr>
<td></td>
<td>00:0726</td>
<td>S-E interacting with apparatus to alter temperatures (shaking the sensors)</td>
</tr>
<tr>
<td></td>
<td>00:14:00</td>
<td>S-E responding to T question of direction of heat flow by looking at graph</td>
</tr>
<tr>
<td></td>
<td>00:17:30</td>
<td>S-Q response Heat flow – the cold water had to attack the hot water because the hot water was hotter</td>
</tr>
<tr>
<td>D1G2FC.1safety</td>
<td></td>
<td>nothing new</td>
</tr>
<tr>
<td>D1G2FC.2bathrety</td>
<td></td>
<td>nothing new</td>
</tr>
<tr>
<td>D1G2FC.3that’s cool</td>
<td>00:00:34</td>
<td>S-E recognizes the change in sensation moving from different water baths “Oh that’s so cool”</td>
</tr>
<tr>
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<tr>
<td>D1G2FC.4temperature</td>
<td>00:01:30</td>
<td>S- Q Response to tub temperature. “Warmer towards the bottom but the heat changed”</td>
</tr>
<tr>
<td>D1G2FC.5heatflow</td>
<td>00:00:46</td>
<td>S-Q Response to heat flow. Very insightful</td>
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<tr>
<td>D1G2FC.6wksheetQ</td>
<td>00:00:21</td>
<td>S-Q response to change in volume of water and how that affects temperature</td>
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<tr>
<td>D1G2FC.7wksheetQ</td>
<td>00:00:49</td>
<td>S-Q response to volume of water</td>
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<tr>
<td>D1G2FC.8sample rate</td>
<td>00:00:09</td>
<td>S-T determining logger pro set up, changing the sample rate</td>
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<tr>
<td>D1G2FC.9predictions</td>
<td>00:00:09</td>
<td>S-T drawing predictions differing between sensor 1 and sensor 2</td>
</tr>
<tr>
<td>D1G2FC.10predictions</td>
<td>00:00:01</td>
<td>S-T drawing predictions</td>
</tr>
<tr>
<td>D1G2FC.11peoples data</td>
<td>00:00:22</td>
<td>S-S visiting other peoples data and comparing predictions to data collection</td>
</tr>
<tr>
<td>D1G3Fcomputingenv</td>
<td>00:00:01</td>
<td>S-T how to work the mouse</td>
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<tr>
<td>D1G3Fprobeware</td>
<td>00:01:09</td>
<td>S-S distinguishing between different parts of the logger pro environment the table from the graphing area</td>
</tr>
<tr>
<td></td>
<td>00:00:41</td>
<td>S-S drawing predictions</td>
</tr>
<tr>
<td></td>
<td><strong>00:02:20</strong></td>
<td><strong>S-T drawing predictions (back of the room)</strong></td>
</tr>
<tr>
<td></td>
<td>00:03:14</td>
<td>S-T drawing predictions</td>
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<td><strong>00:04:00</strong></td>
<td><strong>S-T drawing predictions</strong></td>
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<tr>
<td></td>
<td>00:07:40</td>
<td>S-T teacher modeling apparatus set up</td>
</tr>
<tr>
<td></td>
<td>00:08:19</td>
<td>S-S observing data and walking around looking at others data</td>
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<tr>
<td>D1G3Fprobeware QA</td>
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<tr>
<td>D1G3Fwatertub</td>
<td>00:00:02</td>
<td>S-T Q response the heat from the hands ‘switched’ when you alternated the hands in the tub</td>
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<tr>
<td>D1G3Fwatertub2</td>
<td>00:00:20</td>
<td>S-T Q response difference in water temperature as you change water volume</td>
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<tr>
<td>D1G3Fwatertubexp</td>
<td>00:00:20</td>
<td>S-S Comparing responses to hands in tub</td>
</tr>
<tr>
<td></td>
<td>00:01:00</td>
<td>S-T explaining how to use diagrams to represent sensing water</td>
</tr>
<tr>
<td></td>
<td>00:01:20</td>
<td>S-S comparing water temperature</td>
</tr>
<tr>
<td></td>
<td>00:03:00</td>
<td>S-T Q response to water temperature in</td>
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<tr>
<td>Time</td>
<td>Event Description</td>
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<tr>
<td>00:00:01</td>
<td>D2G1B Calorimetry setup Setting up logger pro</td>
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<tr>
<td>00:00:01</td>
<td>D2G1Breview S-T summarizing day 1 experiments</td>
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<tr>
<td>00:00:05</td>
<td>D2G3simulation S-S working through the simulation interface</td>
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<tr>
<td>00:00:17</td>
<td>D2G3simulation S-T explaining simulation 19.2 with accompanying worksheet</td>
<td></td>
</tr>
<tr>
<td>00:01:44</td>
<td>D2G3simulation S-S feeling in numbers to run simulation, monitor pointing</td>
<td></td>
</tr>
<tr>
<td>00:03:30</td>
<td>D2G3simulation S-T running simulation to try and understand results</td>
<td></td>
</tr>
<tr>
<td>00:04:35</td>
<td>D2G3simulation S-T running simulation and looking for clarification</td>
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<tr>
<td>00:05:20</td>
<td>D2G3simulation S-S developing understanding as a result of running the simulation multiple times</td>
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<tr>
<td>00:06:42</td>
<td>D2G3simulation S-T/S-E discussion on confirming their personal understanding, Re-run animation to recognize differences</td>
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<tr>
<td>00:09:40</td>
<td>D2G3simulation S-S/S-E rerunning simulation to correct earlier misconceptions and based on interaction with teacher</td>
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<tr>
<td>00:00:01</td>
<td>D2G3Bsimulation1 S-T/S-E explaining the role of the simulation in conjunction with the concept of heat capacity</td>
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<tr>
<td>00:01:05</td>
<td>D2G3Bsimulation1 S-T/S-E running animation to observe differences and distinguish between the use of different materials</td>
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<tr>
<td>00:01:50</td>
<td>D2G3Bsimulation1 S-T/S-E comparing differences in the curves</td>
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<tr>
<td>00:03:50</td>
<td>D2G3Bsimulation1 S-T using other examples to relate to how to read the curves</td>
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<tr>
<td>00:06:30</td>
<td>D2G3Bsimulation1 S-S interacting with simulation</td>
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<tr>
<td>00:00:30</td>
<td>D2G3Bsimulation2 S-S interaction with simulation</td>
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<tr>
<td>00:00:01</td>
<td>D2G3Bsimulationmath S-T needed help completing math calculations</td>
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<tr>
<td>00:00:01</td>
<td>D2G3Fsimulation S-S reading text and trying to decide on what numbers to use</td>
<td></td>
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<tr>
<td>00:00:01</td>
<td>D3G1Bcalorimetryconcl S-T sharing data, whole class participation</td>
<td></td>
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<tr>
<td>00:02:55</td>
<td>D3G1Bcalorimetryconcl S-T conducting math calculations, whole</td>
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<tr>
<td>Time</td>
<td>Activity</td>
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<tr>
<td>00:02:55</td>
<td>S-E conducting math calculations, whole class</td>
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<tr>
<td>00:04:00</td>
<td>S-T defining the formula and modeling the math, whole class</td>
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<tr>
<td>00:01:40</td>
<td>S-T working out formula</td>
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<tr>
<td>00:01:43</td>
<td>S-S interaction with weather simulation, comparing the 3 charts</td>
<td></td>
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<tr>
<td>00:02:20</td>
<td>S-T teacher’s brings attention to changes in simulation</td>
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<tr>
<td>00:02:25</td>
<td>S-T what is wind, whole class lecture an important point concerning pressure</td>
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<tr>
<td>00:00:01</td>
<td>S-T discussion on global warming</td>
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<tr>
<td>00:00:01</td>
<td>S-T error in experiments, whole class</td>
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<tr>
<td>00:00:30</td>
<td>S-T finding Nemo, Alfie discusses differences in water and land temperature</td>
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<tr>
<td>00:01:28</td>
<td>S-T review math related to Calorimetry lab, whole class</td>
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<tr>
<td>00:03:21</td>
<td>S-S completing math problem</td>
<td></td>
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<tr>
<td>00:02:11</td>
<td>S-T math problem</td>
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<tr>
<td>00:03:27</td>
<td>S-S completing math problem</td>
<td></td>
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<tr>
<td>00:00:01</td>
<td>S-E setting up simulation</td>
<td></td>
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<tr>
<td>00:01:00</td>
<td>S-T running simulation (poor sound)</td>
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<tr>
<td>00:02:27</td>
<td>S-T working through questions and math problem, trying to decipher the question being asked</td>
<td></td>
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<tr>
<td>00:01:00</td>
<td>S-T What is wind, air pressure, push and pull, Coriolis affect, whole class</td>
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<tr>
<td>00:00:01</td>
<td>S-T completing the problems from day 2</td>
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<tr>
<td>00:01:00</td>
<td>S-S completing the problems from day 2</td>
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<tr>
<td>Time</td>
<td>Event Description</td>
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<tr>
<td>00:03:31</td>
<td>S-T looking for clarification on numbers</td>
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<tr>
<td>D3Gr3BSR3</td>
<td>00:00:01  S-T, discussion on heat capacity (changes dependent on mass) and specific heat (specific substance), whole class</td>
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<tr>
<td>D3Gr33BSR4</td>
<td>00:00:01  S-S solving math problem</td>
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<tr>
<td>D3Gr3BSR5</td>
<td>00:00:01  S-S solving math problem</td>
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<tr>
<td>D4G1Bset-up</td>
<td>00:00:20  S-S troubleshooting equipment</td>
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<tr>
<td>D4G1BTO</td>
<td>00:00:20  S-S setting up interface</td>
<td></td>
</tr>
<tr>
<td>D4G1BTO2</td>
<td>00:00:01  S-T getting more instruction, Where is the Wind. Trying to understand what the data may be telling us. Discussing possible transfer ideas.</td>
<td></td>
</tr>
<tr>
<td>D4G1BT03</td>
<td>00:00:01  S-S interacting with apparatus to further understanding. Re-reading instructions</td>
<td></td>
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<tr>
<td>D4G1BT04</td>
<td>00:00:01  S-S looking for the physical presence of the wind via the apparatus</td>
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<tr>
<td>D4G1BT05</td>
<td>00:00:01  S-T directions of creating representation of lab set up</td>
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<tr>
<td>D4G1BT06</td>
<td>00:00:01  S-S working on representation of possible answer</td>
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<tr>
<td>D4G2BTO</td>
<td>00:00:01  S-T looking for presence of the wind, need clarification on concept, reading data and comparing results</td>
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<tr>
<td>00:02:50</td>
<td>S-S thinking through the problem</td>
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</tr>
<tr>
<td>D4G2BTO1</td>
<td>00:00:01  S-S running through where the sun rises and sun sets</td>
<td></td>
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<tr>
<td>D4G3BTO</td>
<td>00:00:01  S-S thinking through query with exp running</td>
<td></td>
</tr>
<tr>
<td>D4G3TO2</td>
<td>00:00:01  S-T discussing the data capture and comparing line graphs for difference in temperature. Trying to show the relationship between the probes, water and graph</td>
<td></td>
</tr>
<tr>
<td>D4G3TO3</td>
<td>00:00:01  S-T providing explanations of graph</td>
<td></td>
</tr>
<tr>
<td>D4G3TO4</td>
<td>00:00:01  S-S working through their prediction, checking apparatus to confirm ideas</td>
<td></td>
</tr>
<tr>
<td>D4G3TO5</td>
<td>00:00:01  S-T looking for representation validation</td>
<td></td>
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</tbody>
</table>
Discourse interactions matrix

<table>
<thead>
<tr>
<th>Discourse</th>
<th>Interactions</th>
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<tbody>
<tr>
<td></td>
<td>Group 2</td>
</tr>
<tr>
<td></td>
<td>S-S</td>
</tr>
<tr>
<td>Apparatus set up</td>
<td></td>
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<tr>
<td>Learning the interface</td>
<td></td>
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<tr>
<td>Laboratory procedures</td>
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<tr>
<td>Conceptual overview</td>
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<td>Conceptual clarification</td>
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<td>Apparatus-Concept interaction</td>
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<tr>
<td>Interface-Concept interaction</td>
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<tr>
<td>Troubleshooting</td>
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</tbody>
</table>

S-S = Student-Student    S-T = Student-Teacher    S-E = Student-Environment
RI = Rich Interaction (30s) M = Moderate Interaction (10-20s) L = Low Interaction (>5s)
HF = High Frequency (< 4) MF = Medium Frequency (2-3)    LF = Low Frequency (1)