In Search of Student Engagement in High School Physics Through Contextual Teaching

by

Michael Paul Lukie

A Thesis submitted to the Faculty of Graduate Studies of

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in partial fulfillment of the requirements of the Degree of

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Abstract

This action research study compared student intellectual engagement between two different instructional delivery methods. The first instructional method was a non-contextual teaching approach using a textbook to teach the work outcomes for the S4 physics mechanics unit. The second instructional method was a contextual teaching approach where students built an electric guitar pickup and a simple electric guitar in order to provide a context for the teaching of the electromagnetism outcomes for the S4 physics electricity unit. To measure the intellectual engagement of students, data was collected from personal student journals and from questions generated by students following different instructional activities. The student generated questions were categorized and ranked to judge the degree of student intellectual engagement and depth of thought using a framework where numerical values were assigned to the questions. Each question was categorized as peripheral, factual, conceptual, or philosophical where the peripheral questions had the lowest intellectual ranking and the philosophical questions had the highest intellectual ranking. Data was also collected from cumulative unit tests, short exit slips and a personal teacher journal.

The research revealed that students were more intellectually engaged and exhibited much more positive attitudes during the contextual lessons. The questions generated by students during the contextual lessons were of the higher order factual and conceptual types while the questions generated during the non-contextual lessons were predominantly of the lowest order peripheral type. By using the electric guitar and electric guitar pickup as a context, this action research study demonstrated that these

contextual activities intellectually engaged students and helped to facilitate their deeper understanding of electromagnetism.

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CHAPTER 1: INTRODUCTION TO THE THESIS

1.1 Introduction

Physics teachers generally believe that learning should be meaningful and actively engaging for the student. However, such a philosophical teaching perspective does not always align with the way physics is taught. Many out of field physics teachers predominantly use textbook based teaching methods but these methods do not provide a brood conceptual understanding or promote engaging learning activities for the students. Rather than only implementing curriculum through a physics textbook and textbook based problems how can the physics teacher make teaching meaningful and actively engaging for the learner? The challenges are to determine what is meaningful and engaging for the learners, how to modify current teaching practice to include such meaningful and engaging activities, and how to measure such engagement.

1.2 Background to the Study

Standard practice in teaching physics primarily involves teaching electromagnetism though textbook methods where students learn formulas and practice the formulas with end of chapter problems. In my past experience of teaching electromagnetism in this way I have not been satisfied with the level of student understanding. Students have conveyed negative attitudes about electromagnetism, were intimidated by the number of formulas, and students never adequately understood the concepts. Students are not exposed to any real world contexts regarding electromagnetism and this makes the concept very abstract to them. The challenge has been to provide a real world context for electromagnetism that students can relate to and which provides a context for the complicated formulas. The real world context I have chosen for teaching electromagnetism is the construction of the electric guitar and the electric guitar pickup. Through the context of the electric guitar and the electric guitar pickup the formulas and theory of the electromagnetism unit can be used to describe how the electric guitar pickup works. The history of the electric guitar will be used as a door opener providing the contextual background to attract student interest.

1.3 Rationale for the Study

Since I am a mathematics teacher who is teaching physics, I am interested in using a real world context to improve my practice. I want to investigate the efficacy of these contextual methods so that other out of field physics teachers may also benefit. Out of field teaching is a problem for the educational system since "Highly qualified teachers may actually become highly unqualified if they are assigned to teach subjects for which they have little training or education" (Ingersoll, 2001, p.42). In some secondary schools Ingersoll (2001) also reports that more than one half of all secondary school students enrolled in science classes, physics & chemistry, are taught by teachers who did not major or minor in any of these fields. Since many out of field physics teachers lack a sufficient background in electromagnetism I hope that my contextual teaching activities will help other teachers. Getting physics students engaged with learning is very important since recently it has been found that only 30% of Canadian secondary school students are intellectually engaged and that appropriate instructional challenges are required to increase their engagement (Willms, Friesen, & Milton, 2009). Contexts such as the electric guitar can be used to motivate a topic of study and increase student engagement since students are familiar with these contexts.

Metz et al. (2007) and Klassen (2006) both give a contextual teaching framework that I am interested in implementing since Stinner (1994) writes that appropriately designed contexts which attract student's interests often create great motivation to learn science. The story driven contextual approach first grabs students with an interesting historical story and the activities are then motivated from this narrative. Raved & Assaraf (2011) also indicate that a narrative is a useful engagement activity to motivate teaching science. I will be using the history and invention of the electric guitar as my narrative story opener and the activities of building a pickup and guitar will provide the context for the physics outcomes students need to understand.

This study is looking to find if the level of student understanding of electromagnetism differs as a result of using the electric guitar and electric guitar pickup as a contextual teaching strategy. My interest is with student intellectual engagement mostly through the analysis of student generated questions and their personal reflections. I have also included traditional concept tests in the activities because they are typically part of standard physics instruction. The question is how intellectually engaged the students are and how they feel about the contextual instructional strategies I am implementing. Over the long term the contextual teaching approach may bring more students to science and may keep them interested in science longer. Students will have a more lasting understanding of science and students will have a more positive attitude towards science. Osborne (2003) suggests that there is a moderate correlation between attitude and achievement but that feelings of enjoyment in science lead to a positive commitment to science that is enduring. Students will carry that commitment into their daily lives and that is the level of scientific literacy we are trying to achieve with students. For most students this may be their last contact with a science course. It is hoped that the contextual guitar pickup activity will leave them with a positive impression about science and increase their scientific literacy through an interesting learning activity.

1.4 Research Questions

The research objective is to achieve a hands-on physics learning environment where the theoretical and conceptual understanding of physics can be applied to the real world context of the electric guitar and electric guitar pickup. This context is expected to be engaging and meaningful for students since it relates to their own lives. I am interested in determining if the contextual learning activity of building an electric guitar and electric guitar pickup promotes better understanding and positive attitudes for students.

The research questions are:

1. How does the engagement of physics students compare when they are taught using a contextual learning strategy as compared to a non-contextual learning strategy?

2. Do physics students prefer the contextual or non-contextual teaching strategy and what attitudes do physics students have about the contextual and non-contextual learning strategies?

3. How does the level of student understanding of work, energy and electromagnetism compare with my previous experience of teaching without using contextual teaching?
4. Is it possible to motivate S4 physics students in a meaningful, contextual learning activity that facilitates a deeper understanding of the concepts of electromagnetism?

1.5 Significance of the Study

This study is significant because it will add data to the use of the question template as a way of measuring student engagement. This is a new proposed method of measuring student's intellectual engagement developed by Klassen, S., Metz, D., McMillan, B., & Scramstad, C. (2011, in press) and this study will be able to contribute data to this new assessment tool. Since many physics teachers are out of field teachers this study will provide learning strategies for these teachers to more effectively engage their students and teach for understanding. Willms, Friesen & Milton (2009) found that only 30% of high school students are intellectually engaged and this study will contribute to the research on the engagement of secondary students.

There is a gap in the literature about student understanding of electromagnetism and very few studies on the teaching of physics have dealt with electromagnetic concepts (Galili, 1995). There has also been relatively little research on student's understanding of the topic of electromagnetism (Saglam & Millar, 2006). This study will add data to the question of how students understand electromagnetism.

CHAPTER 2: LITERATURE REVIEW

2.1 Students and Engagement

Student engagement is primarily and historically about increasing achievement, positive behaviors, and a sense of belonging in all students (Parsons & Taylor, 2011). Student engagement according to Willms et al. (2009) is:

> The extent to which students identify with and value schooling outcomes, have a sense of belonging at school, participate in academic and non-academic activities, strive to meet the formal requirements of schooling, and make a serious personal investment in learning. (p.7)

Belmont and Skinner (1993), define engagement as follows:

> Engagement versus disaffection in school refers to the intensity and emotional quality of children's involvement in initiating and carrying out learning activities…Children who are engaged show sustained behavioural involvement in learning activities accompanied by a positive emotional tone. They select tasks at the border of their competencies, initiate action when given the opportunity, and exert intense effort and concentration in the implementation of learning tasks; they show generally positive emotions during ongoing action, including enthusiasm, optimism, curiosity, and interest. (p. 572)

Willms et al. (2009), further describes three types of engagement, social, academic and intellectual and the type of student engagement addressed by each. Willms et al. writes:

> **Social Engagement**
>
> A sense of belonging and participation in school life.
>
> **Academic Engagement**
>
> Participation in the formal requirements of schooling.
>
> **Intellectual Engagement**
>
> A serious emotional and cognitive investment in learning, using higher-order thinking skills (such as analysis and evaluation) to increase understanding, solve complex problems, or construct new knowledge. (p.7)

Dunleavy, Milton, & Crawford (2010), have changed the definition of academic engagement to institutional engagement and their new framework for student engagement is now:

> **Social Engagement**
>
> Sense of belonging and meaningful participation in the life of the school (e.g. sports and clubs).
>
> **Institutional (Academic) Engagement**

Active participation in the requirements for school success (e.g. attendance and homework completion).

Intellectual Engagement

Serious emotional and cognitive investment in learning (e.g. students' interest and motivation and relevance of classes to their lives). (p.2)

The new definition of intellectual engagement is described by Dunleavy, et al (2010), in the following way, “The concept of intellectual engagement allows exploration of what students are doing in classrooms, how they feel about their experiences of learning, and whether the work they do contributes to their learning” (p. 2). There are multiple layers and aspects to student engagement as Parsons & Taylor (2011), indicate and as a result there is little agreement on definitions of student engagement.

In the literature, the area that is most lagging is in how to assess or measure student engagement. The lack of research in this area may be due to the difficulty in accessing student engagement and the large number of diverse criteria and definitions (Parsons &Taylor, 2011, p.23). The common quantitative and qualitative measures of student engagement are as follows:

Common Quantitative measures noted in the literature:

1. Attendance/ participation rates/punctuality/graduation rates
2. Achievement/academic levels (standardized test scores and grades)
3. Time on task, homework completion
4. Checklists/Rubrics of completed works

5. Extracurricular participation rates/counts – attendance in sports, arts, after school programs

Common Qualitative measures noted in the literature:

1. Student surveys
2. Teacher surveys
3. Student written or verbal self-report reflections as evidence of critical thinking about learning and levels of engagement
4. Student self-reporting work: Portfolios, products, presentations, student developed projects demonstrating their learning and understanding
5. Observed evidence (increased concentration, interest, motivation, enjoyment) and self-reports of “flow” experiences. (Parsons &Taylor, 2011, p.25)

For this action research study my interest is with the measurement of student intellectual engagement and with the use of student generated questions as a measure of this intellectual engagement. Since I will be collecting data from students about their intellectual engagement using both personal student reflections from journals and student generated questions, I am interested in what the literature says about measuring this type of engagement. Dunleavy & Milton (2009), describe the measurement of academic engagement as:

> In its early development, academic engagement tended to be measured exclusively through observable student behaviours such as time on task or homework and assignment completion. Over time, researchers have also begun to explore the influence of more individualized measures, such as interest and personal effort, strategies for strategic learning, sense of competence, perceptions of social support for learning, and so on (Dunleavy & Milton, 2009, p. 8).

In this research student generated questions are being used as an indicator of student intellectual engagement and the questions will be ranked according to the guidelines from Klassen et al. (2011). Students who generate peripheral question responses are at the lowest level of intellectual engagement. Factual question responses indicate that students are more engaged but they are asking very simple basic questions. Conceptual question responses relate to scientific explanation, clarification, hypothesizing, and testing and therefore indicate that a student is actively involved in thinking about what is going on in the classroom. Finally, the philosophical questions indicate the highest level of critical. In this way, the analysis of student generated questions is being used as a measure of student intellectual engagement. Once the question data is collected, scoring values will be assigned to the question framework categories so that student intellectual engagement may be statistically analyzed, see Section 4.7.

Dunleavy & Milton (2009), write that "Because intellectual engagement is a new concept, it is difficult to pinpoint which classroom practices will be most effective in supporting it." (p.13). Dunleavy & Milton (2009), suggest the following :

> From what we know so far, however, designs for learning that begin with the goal of intellectual engagement lead to instructional choices that:
>
> 1. Emphasize conceptual learning and opportunities for students to work with **authentic ideas and problems**, develop a deep understanding of ideas, sort through misconceptions, learn new ideas and create or improve upon ideas, see conceptual **connections across disciplines**.
> 2. Require high levels of **student participation** and provide time for in-depth work.
> 3. Incorporate **authentic assessment** as a strategy that helps students set goals and assess their own learning.
> 4. Use work that is **relevant, interesting, and connects with students' aspirations**; is rigorous and allows students to think as "professionals" and create professional" quality outcomes; is challenging and allows students to experience a sense of deep **intellectual and emotional investment** in learning; is built from
>
>   diverse and improvable ideas; and is informed by the current state and growing knowledge bases of different subject disciplines.
> 5. Promote students' **sense of ownership** and responsibility for their own learning.

6. Invite students to be **co-designers of their learning** in classrooms; support student voice and autonomy.
7. Provide a **high level of social support** for learning and encourage students to take risks, ask questions, and make mistakes.
8. Foster **collaboration** and **community building**.
9. Engage students in becoming **literate with technologies** as social networking knowledge building tools.
10. Connect students with opportunities to **develop abilities in critical thinking,** intellectual curiosity, reasoning, analyzing, problem solving, communicating, etc.
11. Bridge students’ experience of **learning in and outside of school** by exposing them to digital technologies in knowledge building environments (p. 13-14).

This research is summarized from the students' perspective by Dunleavy, Milton, & Crawford (2010) when they write:

> Students want to experience work that is meaningful, not easy: they want to work with ideas that matter, solve real problems, learn from each other, people in their communities, and experts in the subjects they are studying, engage in dialogue in their classes, and know that their learning contributes to making a difference in the world. They consistently demand to be respected (p. 1).

This research study using a contextual teaching approach illustrating the history of the electric guitar and the building of an electric guitar pickup addresses many of the points from Dunleavy & Milton (2009). Some of the instructional designs incorporated in the contextual electric guitar and electric guitar pickup teaching approach include: relevant, interesting, connects with students and after students build the guitar pickup they have a sense of ownership.

The literature suggests that further research needs to be done in defining student engagement and there needs to be more research in how the different types of engagement interplay with one another. Parsons & Taylor (2011), specifically suggest that there needs to be more teacher involvement and input into research about engagement and students need a voice in this research.

2.2 Student Attitudes

Raved & Assaraf (2010), indicate that an attitude is a general term encompassing students' orientation or relation (be it positive or negative) towards a particular object or event (in this case-the study of science).

Bybee & McCrae (2011), surveyed fifteen year old high school students from 57 countries about their attitudes towards studying science. The survey was undertaken by the Programme for International Student Assessment (PISA) and it gathered data on students' interest in science, support for scientific inquiry, and responsibility towards resources and environments. The PISA group believes science curricula takes the position which emphasises educating future scientists versus educating future citizens. The survey makes connections between students' attitudes and interests in science and scientific literacy. The ability of students to apply their knowledge and skills is the key point, because that is what they will have to do as citizens. The article states that students' attitudes subsequently influence their willingness to engage in science-related issues and with the ideas of science as constructive, concerned, and reflective citizens. The survey found that Canadian students ranked third in interest in learning science topics but showed that the more developed a country is, the less positive young people are towards the role of science and technology in society. In terms of student interest in broad science topics, physics was ranked fifth out of eight topics and the topic related to scientific explanations was ranked last. Although there was interest in studying physics students had the least interest in learning about abstract scientific explanations which is predominant in the physics curriculum. Students were most interested in topics that they perceive as being relevant to their lives, and least interested in the topics that they perceive as being of little relevance (Bybee & McCrae, 2011).

Raved & Assaraf (2011), and Osborne (2003) indicate that for students to have a positive attitude toward science they need to find a connection between the subjects studied in science class and their everyday lives. This suggests that connecting science study subjects to the students' real life through a narrative and relevant and current examples, and thus helping the knowledge and skills gained in science class to be meaningful and relevant to the students' world, can help ensure that this knowledge becomes internalized and induces interest, satisfaction and pleasure (Raved & Assaraf, 2010).

Since electromagnetism uses abstract scientific explanations and since students cannot see how it relates to their lives, their attitudes towards studying this topic is very low. By using the electric guitar pickup as a context to teach electromagnetism students can relate this topic to their lives through music. Most students like rock and roll and there would be no rock and roll without the electric guitar and the electric guitar pickup. When I have taught the electromagnetism unit in the past students have commented on how they cannot relate to the abstract formulas and complex mathematics involved and could not see anywhere they would ever use what they were learning. By incorporating the abstract mathematics within the guitar pickup I would hope student attitudes and engagement would increase. There is much to be done in researching the area of student interest, attitudes and engagement and this research is an attempt to add to that body of knowledge.

In terms of engagement, current research shows that levels of participation and academic engagement fall steadily from grade six to grade twelve, while intellectual engagement falls during the middle school years and remains at a low level throughout secondary school (Willms, Friesen, & Milton, 2009). Canadian students have very low levels of engagement and the Willms et al. (2009) study suggests that less than one-half of Canadian students are deeply engaged in their study of school subjects. It is suggested that in order to increase the level of engagement in the classroom students require an appropriate instructional challenge. When students are confident in their skills but do not feel challenged they are also more likely to experience lower levels of engagement. The challenge is to find a balance between the interaction among dimensions of a student's engagement, namely the dimensions of academic, social and intellectual engagement (Willms et al., 2009).

There is little support for any strong relationship between attitude and achievement and at best there is only a moderate correlation between attitude towards science and achievement. Osborne (2003), indicates that feelings of enjoyment and interest in science combined with success in junior science courses are likely to lead to a positive commitment toward science that is enduring but that students can still achieve highly in science without holding a positive attitude towards it. In my opinion students who do achieve without investing some of their own intellectual capacity without being engaged will not have an enduring positive commitment to science. These student are the ones that we are only teaching for a moment in time and are only interested in passing a test. I think that by using the contextual approach, the teacher can help develop more positive student attitudes and students will have a more positive commitment to science that they will take with them through their lives and into the future.

2.3 Teaching and Engagement

In the literature on engagement Willms et al. (2009) suggests two important aspects about teaching practice that use contextual teaching in order to increase engagement of students.

In order to increase engagement Willms et al. (2009) suggests the following:

> First and foremost, effective teaching practice begins with thoughtful, intentional designs for learning – designs that deepen understanding and open the disciplines to genuine inquiry. One of the hallmarks of the new science of learning is its emphasis on learning with understanding. This means that teachers must go beyond developing techniques to implement the curriculum. Curriculum topics

> are not objects that can be disassembled and treated as if they were authentically learnable, independently and without regard to the relationships among the parts. (p. 33)

Secondly Willms et al. (2009) write:

> The work students undertake also needs to be relevant, meaningful and authentic in other words, it needs to be worthy of their time and attention. Too frequently, the work students are asked to do does not allow them to use their minds well or to experience the life and vitality of real, intellectually rigorous work. Once fragmented, school work loses its intrinsic, disciplinary and intellectual meaning. In this form, the work cannot have any meaning or value to students beyond the achievement of high marks. (p.34)

Willms et al. (2009), further states that effective teaching is characterized by thoughtful design of learning tasks that require and instil deep thinking, immerse the student in disciplinary inquiry, are connected to the world outside the classroom, have intellectual rigour and involve substantive conversation. Stinner (1994) writes,

> Learning in physics could be well motivated by a context with one unifying central idea capable of capturing the imagination of students. Large context problems (LCP) are contextual settings that generate questions and problems that seem inherently more interesting than similar problems presented in textbooks. (p.375)

The immediate benefit of contextual problem solving seems to be that it enlarges the students' understanding of the basic laws and principles. The use of the historical development of the electric guitar and electric guitar pickup will provide the large context for the following contexts of inquiry, contexts of questions, method, problems, experiments and history. Problems based on this unit are designed to attract students' interest and to create a motivation for learning science with one unifying central idea, the electric guitar. Stinner (1994), suggests that there is strong evidence indicating that learning methods imbedded in context are not just useful, but are essential.

The history of the electric guitar is expected to capture the imagination of the student, generating questions and problems more interesting than similar questions and problems presented in their physics textbook. The physics of electromagnetism will be imbedded into questions and investigations that naturally flow from the electric guitar as a context of inquiry. The context of inquiry structure is very important since it is the pedagogical scaffolding that illuminates the status of theory, establishes what counts as evidence, clarifies the relationship between experiment and explanation and makes connections to the history of science. The history of science is important since it helps to humanize scientists making it easier for students to relate to them (Stinner, 1994).

Klassen (2006), describes 5 distinct contexts of science learning which are the practical, theoretical, social, historical and affective. In a learning situation these contexts interact with one another and it is desirable for learning to take place in more than one context at a time. This is a method by which a lesson can be facilitated in a contextual fashion. Klassen (2006) writes:

> Even though these contexts naturally operate together in typical learning situations, it is the affective context, created by a story, which can produce the incentive desired at the beginning of a lesson. The story focuses attention and motivates, which is why it is a good starting point for any learning episode. For that reason, I have chosen to call my theoretical framework for contextual teaching the *Story-Driven Contextual Approach* (SDCA). (p.54)

The story is the component entering the learning process and in my case it will be the history and invention of the electric guitar. The next step is for the teacher to formulate a set of related problems that might form the basis for a group student investigation. The investigation I will facilitate is the construction of an electric guitar and electric guitar pickup and it will have both an experimental and theoretical component. The student is seen as a novice researcher and the teacher plays the role of research leader providing expert advice and supervision as students begin to formulate ideas and perform activities. In this way students are given a high degree of responsibility for their own learning. The students at the end of this process will finally present a report on their investigation. In the case of my study the students, after having learned progressively more complex theory about electromagnetism, will present their student built electric guitar pickup to the class explaining in detail how aspects of electromagnetism make it work. Klassen (2006), writes that in his experience students show significantly more enthusiasm over being able to report results to their fellow students verbally.

Several ways of using science stories have been identified in the literature (Metz et al., 2007). In my research I have chosen to use the story of the history of the electric guitar and electric guitar pickup as a "door opener" to instruction. (Kubli, 2005, Metz et al., 2007, p.403). Metz et al. (2007) write:

> Stories to be used as door openers do not have as their primary purpose the explanatory function, but they are intended to make the concept being taught more memorable, to help reduce the distance between teacher and students, and to assist in illuminating a particular point being made. (p.317).

The history of the electric guitar and electric guitar pickup is an excellent method to reduce the distance between the student and teacher. Teachers and students are very connected to music in their lives and by bringing up music to them the distance between the teacher and student is reduced because music is what is in common. The story involving the need to increase the volume of the acoustic guitar is illuminating the need for an electromagnetic pickup. Klassen (2009), writes that the door opener provides reasons for needing to know.

> Door opening science stories provide “reasons for needing to know.” Another, perhaps more significant purpose behind such stories is to raise questions or leave the student with unresolved problems or issues which form a significant part of the science material being taught. These questions arise not only from the

story itself, but from the scientific issues and science concepts that the story contains. (p.403).

In my research the significant part of the science material being taught is electromagnetism and this leaves student with questions about how these concepts will be applied to the electric guitar pickup.

2.4 Romantic Understanding

In my past experience I found it very difficult to motivate my students and get them inspired about electromagnetism. I have previously used the textbook to teach these concepts and I have found students were bored and not interested with the topic. In addition, when my students see all the formulas associated with the electromagnetism unit they are immediately turned off and not interested. When searching for an authentic context to teach electromagnetism I looked back to my high school days in the late eighties when I was into music and had a blues band. Since I was passionate about music in my late teens I expected the students in my physics class would also be interested in music. At this age most teenagers like music and I felt I could pass on my enthusiasm about the electric guitar to them. Since the students would be learning about electromagnetism through an authentic and memorable context of building an electric guitar and electric guitar pickup I expected their engagement and understanding to increase. What I attempted to do was to design an activity that tapped into their prior knowledge, a knowledge of music or of playing a musical instrument. The activity of building the guitar was not a contrived activity and the authenticity of a student being able to build a guitar and pickup they could then take home and use was appealing to me as a physics instructor.

Winchester (1989), referring to Whitehead (1929), writes that learning exists in three phases for a given area of interest. The first phase involves initial excitement and puzzlement, the second phase involves mastery of skills relating to the specific problem connected with the initial excitement and puzzlement, and finally the third phase that goes beyond the initial realm of interest to a new and connected realm. He further writes,

> Our present methods (except in the hands of an exceptional teacher) emphasize precision only and for most, it is either an empty precision, or a failure to master the precision expected. In most cases this means that generalization is not possible and further romance is squelched." (Winchester, 1989, p.i).

Whitehead (1929), identifies these stages as romance, precision, and of generalization. Since I have been using the textbook for the last number of years when teaching electromagnetism, I have been emphasizing the precision stage or the mastery of skills stage and I have been minimizing any romance the student may have for the topic. As Winchester (1989) writes, I have been simply teaching the "how to" in the initial stages building to precision and leaving out the romance.

By introducing the activity of students building the electric guitar and pickup I am trying to tap into the student love of music and inspire some romance within this complicated topic so that students will move their learning to a connected realm. What I have been teaching in the past was "empty precision" (Winchester, 1989, p.i) and what I wanted was Whitehead's stages of romance, precision and generalization. The introduction of the history of the electric guitar is the romance stage and it has "the vividness of novelty; it holds within itself unexplored connections with possibilities half-disclosed by glimpses and half-concealed by the wealth of material." (Whitehead, 1929, p.28). The construction of the electric guitar and electric guitar pickup is the stage of precision where the "width of relationship is subordinated to exactness of formulation", and forces students to accept "a way of analyzing the facts bit by bit." (Whitehead, 1929, p.28). The final stage of generalization synthesizes and connects all of the electromagnetism concepts together. At this stage, "It is a return to romanticism with added advantage of classified ideas and relevant technique." (Whitehead, 1929, p.28).

Just as Whitehead wrote about romance, Hadzigeorgiou et al. (2011), write that teachers should be encouraging a romantic understanding of a concept. "There are learning benefits to students when encouraging a romantic understanding of a concept since students become involved with the content and context." (p.8). Since I wanted to increase student understanding of electromagnetism I wanted to use the electric guitar to facilitate the development of student's romantic understanding. Hadzigeorgiou et al. (2011) write:

> In order to facilitate the development of romantic understanding, it is necessary for science teachers to identify heroic qualities that relate to the specific science content to be taught and to organize this content within a narrative structure. The heroic qualities, in particular, can capture the main narrative thread and, thereby, help maintain students’ attention from the beginning to the end of the lesson. (p.8)

All the aspects of romantic understanding are inherent in the story of the history and invention of the electric guitar and the electric guitar pickup. There are five aspects of romantic understanding inherent in a narrative and they are:

(a) the human context is used

(b) a sense of wonder is evoked

(c) some limits of reality and extremes of human experience are exposed

(d) heroic character traits are applauded

(e) conventions and prevailing ideas are contested.

(Hadzigeorgiou et al., 2011, p.8)

The human context with the narrative of the history and invention of the electric guitar was the need to solve a problem of increasing the volume of the acoustic guitar. As the popularity of music increased the audiences became larger and the guitar could not be heard. The question of how physics will play a role in solving the guitar volume problem should evoke a sense of wonder with students. Many people were trying to solve the problem of increasing the guitar volume and much innovation and scientific experimentation was being done in the process. The limits of human ingenuity were being pushed and although many ideas were tried, no solution seemed to be at hand. Prior to the invention of the pickup a number of innovations were made to the acoustic guitar and students will be made aware by the narrative that the solution progressed from simple mechanical solutions such as increasing the size of the guitar to a complicated electromagnetic guitar pickup solution. The narrative involves many heroic characters who persisted in the face of adversity. Les Paul used a phonograph needle and telephone parts embedded in an acoustic guitar in an attempt to amplify a guitar (Smith, 2004). Leo Fender was accused of stealing the idea of his electric guitar from Merle Travis and Paul Bigsby, and ultimately had to change the name of his guitar from the Broadcaster to the Telecaster because of copyright issues. The solution to increasing the guitar volume was the electric guitar pickup but the first design was contested by the patent office since no one believed it was functional. Students should find it very interesting that the inventor of the first electric guitar, Beauchamp, had to take a band to the Washington, D.C. patent office to play for the patent officials in order to prove that his guitar pickup amplified his guitar (Smith, 2004).

In addition to Whitehead's stages of romance, precision and generalization, romantic understanding can be used to facilitate a deeper understanding of electromagnetism by using the concept of the electric guitar.

2.5 Student Misconceptions About Electromagnetism

Concepts of electromagnetism were most frequently mentioned in the literature as potential sources of difficulty for students. Teachers found that the mathematical representation of the concepts were a real barrier to understanding and students have difficulty in using relationships and models which are specific to magnetic phenomena. It seems that the electromagnetic concepts constituted “islands” which most students did not connect fully (Albe, Venturini & Lascours, 2001). The students were not able to bring together different elements of knowledge and had problems associating mathematical formulas with the physical descriptions of electromagnetism. Students could not use the electromagnetism formulas in elementary situations and that the link to mathematics was entirely procedural. This procedural link indicates that there is no student understanding about theories and concepts but only indicates their ability to use algebra to manipulate formulas. Saglam & Millar (2006), agree that the introduction of formulas and other mathematical notations may impede rather than promote the understanding of the basic physics principles. I have also found this in my practice, students are overwhelmed by the number of equations in the electromagnetism unit and they cannot conceptually understand the relationships between the variables but can algebraically manipulate the variables.

Galili, (1995) indicates that the way students learn the concept of the field lead to a number of misconceptions. He writes that students must understand what a field is before the field is taught within the context of the electromagnetism unit since the concept of the field presents a high conceptual difficulty for students. Galili also indicates that the concept of the field is commonly introduced in teaching electromagnetism only through the formal operational definition, it could falsely affect the understanding and lead to adopting of other problematic general principles previously grasped by students while learning mechanics (Galili, 1995).

The literature also suggests that underlying many student misconceptions are the difficulties they have in coming to terms with an abstract model (involving constructs and variables such as: magnetic field, magnetic field lines, magnetic flux through areas, rate of change of flux, potential difference, etc.) and learning how to use the model in new situations. Students also lack a sense of confidence in their understanding, and leads to a consequent tendency to guess answers rather than try to reason carefully (Saglam &

Millar, 2006). In this research using the story of the history of the electric guitar and the electric guitar pickup is being combined with a series of demonstrations, laboratory activities, and the bldg of electric guitar pickup. These activities are designed to help instill a sense of confidence in the students in order to more authentically examine the ideas of magnetic field, magnetic field lines, magnetic flux through areas, rate of change of flux, potential difference, etc.

CHAPTER 3: THE HISTORICAL DEVELOPMENT OF THE ELECTRIC GUITAR

The motivation behind the invention of the electric guitar was the need to increase the volume of the guitar. As musical performances moved to increasingly larger public spaces in the late 19th and early 20th century, the size of musical ensembles grew correspondingly and guitar musicians required more volume so that they could be heard. With the rise of big band music and radio in the 1920's the quest for guitar volume intensified since it was becoming increasingly more difficult to hear the guitar in noisy and crowded dancehalls or in the recording studio.

Prior to the 1920's a series of design innovations had been incorporated into the acoustic guitar that are important to the quest for increased guitar volume. Around the 1850's Christian Frederick Martin introduced X-bracing which was used as a structural support for the interior body of the guitar, three tuners on each side of the headstock and a body shape that was smaller above the sound hole than below (Martin, 1998, p.91; Usher, 1956). The X-bracing allowed for larger and larger guitars to be built but with each increase in size came a disproportionately small increase in volume. These innovations became standard for all acoustic guitars until Orville Gibson applied for a guitar patent on February 1, 1898 where, "the top and bottom of the instrument are carved rather than flat (as found on the soundboards of other mandolins and guitars)" (Martin, 1998, p.94). The "arched top" innovation gave the guitar much more volume than had been achieved with just guitar body size and X-bracing. In 1924 Gibson acoustical engineer Lloyd Loar developed the first coil-wound non-electromagnetic guitar pickup but soon left Gibson since Gibson believed the electric instruments would not be financially viable. Loar's first pickup "used the instrument’s physical vibrations, as transmitted through the bridge, to vibrate a diaphragm stretched over the pickup and create an electrical signal." (Smith, 2004, p.2).

The next major design innovation was the resonator cone which was invented by John Dopyera who applied for a patent on April 9, 1927. The resonator guitar had a bridge resting on three aluminum cones known as the "tri-cone system" and the guitar's wood on the back and neck of the guitar was replaced with nickel plated, often heavily engraved silver (Martin, 1998, p.99). Although this style of guitar, marketed under the "Dobro" or "National" brand names were louder than wooden guitars, their tone was brash and did not produce the desired tonal characteristics of the conventional acoustic guitars of the day.

In 1925 the Grand Ole Opry began broadcasting a radio program which became very popular and as the popularity of the radio show increased so did its audience. Popular groups started to be recorded and these recordings were usually made directly to phonograph disks by using an acoustical recording horn or by using a single microphone. The recording engineers soon realized that something needed to be done to boost the guitar's volume since it could barely be heard in the recordings. At live performances larger and larger audiences found it increasingly more difficult to hear the guitar and a major innovation was desperately needed.

The most important innovation that increased the volume of the guitar was the electric guitar pickup. "The principle of the guitar pickup is fairly simple - a magnet (or group of magnets) is surrounded by a very thin copper wire, wound around it many times, through which the vibrations of the strings are turned into an electric current which is then sent to an amplifier" (Martin, 1998, pg.99). The first commercially made electric guitar is referred to as the "Frying Pan" due to its shape and it was introduced by the Rickenbacker International Corporation which was founded by George Beauchamp and Adolph Rickenbacker. In late 1931 Beauchamp built an electromagnetic pickup and filed for a patent on June 2, 1934. Beauchamp's pickup had a coil under the strings and two massive magnets with moderate attractive force extending over the strings in a configuration shaped liked a horse-shoe. In addition, six cylindrical pole pieces inside the coil directed the magnetic flux towards the strings (Milan, 2007, pg.15). The patent was not given to Beauchamp until 1937 since the patent office did not believe it would work. The Rickenbacker company manufactured several models of the electro Hawaiian steel guitar in the 1930's and 1940's and incorporated materials such as steel and Bakelite into their design. From this successful base of manufacturing Hawaiian guitars the company moved into producing solidbody Spanish style guitars. The Electro String Vibrola was introduced in 1937 and these first electric guitars were sold as sets with an included guitar amplifier (Milard, 2004, pg.56).

In 1934 the Gibson Company began to make electric Hawaiian guitars but it was not until 1936 that Gibson finally introduced an electric Spanish guitar or the ES guitar . The ES electric guitar, named the Gibson ES-150, was popularized by Charlie Christian and it soon won the respect of musicians and the admiration of audiences (Brosnac,1983, p.15). The pickup used on the ES-150 was designed by Walter Fuller at Gibson and it became known as the "bar pick-up" because it had a "bar" as the dominant magnetic pole. Around this bar, or blade, Walter Fuller had placed the coil, while two magnets were set perpendicular to the blade and parallel to the strings (Duchossoir,1981,p.15). "In 1938 the coil of this bar pickup was changed to 10000 turns of AWG 42 wire for a resistance of 8KΩ with a 20% tolerance and this configuration set the standard regarding coil specifications for later pickup models up to the sixties." (Milan,2007, p.20).

The last innovation in the invention of the electric guitar, and the final break with the guitar's acoustic past, was the solid body. The electrified acoustic guitars of the 1930's and 1940's filled the need for volume but their performance was marred by unwanted resonance of the acoustic sound box at high volume. With both the wood and the strings of the instrument vibrating, the amplified acoustic guitar produced a loud feedback hum. The electrified acoustic guitar was a compromise between two completely different amplification systems, the traditional acoustic system and the new electric system. The abandonment of the acoustic system and the adoption of a solid, immoveable base for the electric pickup was the next important step forward in the electric guitar design (Milard, 2004, p.50). In 1941 Lester William Polfus, (Les Paul), experimented with the solid body electric guitar by stringing a 4 by 4 inch piece of solid pine and attaching it to a Gibson neck (Duchossoir,1981, p.56). When a string was plucked on this experimental guitar the note sounded on and on with hardly any reduction in the sustain of the note. Les Paul called this guitar the "Log" but never pursued the design commercially (Millard, 2004, p.50). Around 1947 Paul Bigsby, a Los Angeles machinist, teamed up with the country singer and guitarist Merle Travis to design a solidbody electric guitar and this design may have been later adapted by Leo Fender in 1950. Leo Fender's adapted solid body guitar had a single coil pickup and a bolt-on neck that could be easily attached in the manufacturing process (Millard, 2004, p.57). The first Fender production model was a one pickup instrument called the Esquire which was soon followed by a two pickup model called the Broadcaster. The Broadcaster had to be renamed to the Telecaster in 1952 however since there was a trademark dispute over the Broadcaster name (Milan, 2007, pg.28). The Telecaster became the world's first commercially successful solidbody electric guitar. The instrument had a single-cutaway solid slab of ash for a body and a screwed on fretted maple neck. It had a slanted pickup mounted into a steel bridge-plate carrying three adjustable bridge saddles and the body was finished in a yellowish blond color (Bacon & Day, 1992, pg.14).

In 1952 Gibson became Fender’s first major competitor in the solidbody market with the introduction of the Gibson Les Paul. This guitar was primarily designed by Gibson’s Ted McCarty and was endorsed by Les Paul. "This new guitar was built from solid seasoned mahogany and a carved maple top, with aesthetic and functional details rooted in the rich lutherie tradition. " (Milan, 2007, pg.28). Les Paul’s design input included the original trapeze-style combination bridge-tailpiece, and the gold finish which inspired the instrument’s nickname, the Goldtop. The gold color was intended to disguise from competitors that the guitar had a maple cap on a solid mahogany body. According to a company history, the idea of using two kinds of wood was to balance the bright attack of maple with the warmth and richness of mahogany (Smith, 2004, pg.4).

Fender made further innovations to the electric guitar and introduced the Stratocaster in 1954. This electric guitar had three single coil pickups connected in parallel producing a bright tone, a custom contour body and a bridge tremolo system. Gibson also continued to innovate and in 1955 Seth E. Lover developed a pickup that reduced the hum a guitar made when played through an amplifier. The humbucking pickup had two single coil pickups that were connected in series and out of phase which cancelled the unwanted pickup hum (Milan, 2007, p.33). Since the single coil pickups were connected in series the resistance in each coil added together to make the resistance of the whole pickup giving this new humbucking pickup a thicker sound and higher output (Raymond, 2001, p.74).

In an attempt to increase the volume of the acoustic guitar a series of design innovations were implemented over a hundred year period spanning from 1850-1950. The acoustic guitar changed from being hollow, where volume was controlled by size and a resonating cavity, to the solid body electric guitar, where volume was controlled by an amplifier and an electromagnetic pickup. The history and invention of the electric guitar is a story about the solution to a problem, how to increase guitar volume, and whose solution, the pickup, ultimately involved physics. It is hoped that the story will draw students in so that they become interested in how the guitar pickup works. By building a pickup it is hoped that the engagement of the hands on activity will help to increase student understanding of a conceptually difficult physics topic.

CHAPTER 4: METHODOLOGY

4.1 Introduction

In this study I focused on S4 physics students at an independent Winnipeg , MB high school where I have been teaching fulltime since 2004. These students were involved in a one week study which covered the electromagnetism outcomes of the electricity unit and the work outcomes of the mechanics unit of the S4 physics curriculum. The study examined the degree to which students were engaged in learning, their attitudes to two different instructional methods, and the extent to which their learning benefited from creating an electromagnetic guitar pickup as a contextually based activity.

I compared two different instructional delivery methods. The first instructional method was a non-contextual teaching approach using a textbook to teach the work outcomes of the mechanics unit. The second instructional method was a contextual teaching approach where students built an electric guitar pickup and a simple guitar in order to facilitate teaching the electromagnetism outcomes of the electricity unit. I was interested in comparing the levels of student engagement and student attitudes between the non-contextual and contextual teaching approaches. To measure student engagement, I collected student generated questions following a number of different instructional activities. To measure student attitudes, a combination of student journals and exit slips were employed to collect evidence. The questions that were collected were categorized and ranked to judge the degree of student engagement and depth of thought using a framework where numerical values were assigned to questions which were either, peripheral, factual, conceptual or philosophical in nature. This questions framework was considered to be valid as a research instrument since, "Based on the high degree of correlation of the data against theoretically-generated points from a normal distribution, we adopted the assumption of normality as being justified and unproblematic." (Klassen et al., 2011, pg.11).

4.2 Action Research

The development of this contextual teaching approach is highly personal and based upon my skills as a teacher and musician. I designed this activity so that students could build their own guitar and guitar pickup in a reasonable amount of time. Other teachers may not have the expertise to implement these activities but following this study I will be able to produce classroom resources for other teachers to use. The activity was intended to inspire and motivate other teachers to use a contextual method in an area of their expertise so that they may bring their hobby or skill to the classroom and engage their students.

4.3 Ethical Issues

In this study I was the students' teacher so there was a risk to them as participants as I was in a position of power over them. I was aware of this risk and took exhaustive measures to ensure that the student data remained anonymous. The Administration of the high school where the research was conducted was first contacted with an administration letter of recruitment and then received an administration letter of consent to sign (Appendix A, Appendix B). In order to obtain informed consent from the students involved in the research, a school secretary distributed the forms to the students when I was not in the room and who informed students about the proposed research. The secretary read a short description to the students which informed them about the nature of the research (Appendix C). The students who were under the age of 18 were required to sign a letter of informed assent and their parents were required to sign a parental letter of informed consent if they allowed their child to participate in the research (Appendix D, Appendix E). For students who were over the age of 18 they were only required to sign a letter of consent (Appendix F).

The informed consent letters were collected by the school secretary who made a list of which students participated in the research and then secured this information. Once the informed consent list was obtained, each student was given a numerically assigned data folder. Each time data was collected, the students entered their data in their corresponding numbered folder and at the end of class they put their folders into the class filing cabinet. The cabinet was locked at the end of each class and I never knew which student corresponded to which numbered folder. I only analyzed the research data after the final grades had been assigned in April so that student final grades were not biased by the research or by the knowledge of which students are participating.

To further ensure that the student data remained anonymous, the following protocol was given to administration to follow:

1) After the consent letters have come into the office make a list of students who consent to participate and make a list of students who do not consent to participate. In the event that a parent provides consent and a student does not provide assent or in the event that a student provides assent and a parent does not provide consent, this student name will be added to the

list of students who will not be participating in the study and whose data will not be used. This list must be kept strictly confidential by locking it in a secure cabinet in the office. In the event that a student should suddenly drop out of the study their name will be added to the list of students who are not providing consent and their data folder including all documents must be shredded and disposed of.

2) After final grades have been assigned in April you will be given all the data folders that have been stored in a locked cabinet in the classroom. Remove the folders of the students who have not given consent, shred them, and dispose of them.

3) Cut the names off the remaining folders.

4) Give the researcher the anonymous data folders so that the data may be analyzed.

The student data will not contain any identifying information and this material will be stored in a locked filing cabinet where only I will have access to the information. The material will be stored for the duration of the study and then shredded by October 2012.

This study was given a research ethics approval on January 13, 2012, Protocol #E2011:118, (Appendix G).

4.4 Data Collection

I collected data about student engagement and student attitudes throughout the planned lessons. Data about student engagement and attitudes was collected from student generated questions, rotational graffiti, exit slips, final unit assessments, and student journals. Students were provided with a journal where they wrote all of their responses to their attitudes about the instructional strategies. I also kept a journal and a record of my practice as part of this action research study.

4.4.1 Student Questions

Student generated question data was collected eleven times throughout both the contextual and non-contextual learning activities. During the non-contextual learning activity, students had the opportunity to generate questions three times, while during the contextual learning activity, students had the opportunity to generate questions eight times. The students were encouraged to write down as many questions as they had about the learning strategies on the provided question sheets.

4.4.2 Student Journals

At the end of every lesson the students wrote in their journal about the instructional strategies presented in the lesson. Since students responded at the end of every lesson there was a total of eight journal responses per student. The students provided a response to the following prompting questions in their student journals:

1) What did you like?

2) What did you not like?

3) Comment on the way the lesson was presented.

4) Comment on your level of your engagement.

5) Comment on how the lesson interested you.

4.4.3 Rotational Graffiti

Rotational graffiti was used twice to test for prior understanding and as a learning activation strategy. The questions the groups of students wrote or drew about for the non-contextual learning strategy (Appendix H) are the following:

Write what you know about energy.

Write what you know about force.

Draw things you push or pull.

The questions the groups of students wrote or drew about for the contextual learning activity (Appendix I) were the following:

Write- What role does music play in your life?

Draw- What role does music play in your life?

Write- How do musical instruments work?

Draw- How do musical instruments work?

Write- Where do you find electricity and magnetism in your daily life?

Write- Explain about electricity and magnetism?

Draw- Explain about electricity and magnetism?

The student groups presented their rotational graffiti to the class after they did the activity for both the non-contextual and contextual learning strategies.

4.4.4 Exit Slips

Since I needed to ensure that students were learning the curriculum outcomes for electromagnetism, I gave 2 small formative assessment exit slips from Lesson 3

(Magnetic Flux) and Lesson 4 (Lenz's Law) of the contextual teaching activity. Each exit slip consisted of a short question that students had to answer. (Appendix J, Appendix K).

4.4.5 Final Unit Assessments

I gave a separate summative assessment at the end of both the non-contextual and contextual teaching strategies. A formal paper-pencil test was given in both cases and all of the concepts about work and electromagnetism were tested and mathematical problems related to the laws and formulas presented during the two units were formally assessed. The tests gave students an opportunity to demonstrate their level of understanding of the curriculum outcomes for the S4 physics work and electromagnetism unit (Appendix L, Appendix M).

4.4.6 Teacher Journal

Throughout the unit I kept a teacher researcher’s journal and I wrote in it every day. In this journal I kept track of student activities and responses to my teaching and wrote evidence of student thinking and learning. I focused on recording activities that engaged students. Since I was looking to increase engagement through the guitar pickup as a context I was interested in recording moments in the lessons where students were working in a meaningful context.

4.5 Non-Contextual Teaching Strategy

As an "out of field" physics teacher I have relied heavily on the use of textbooks to teach physics. The more I have taught however, I realize that as a result of using textbooks "the normal pattern of science learning is memorization and algorithm memorization" (Stinner,1992, p.5). In this way students are not learning physics since they are simply memorizing equations and memorizing algorithmic solutions to exemplars. The typical physics textbook is full of knowledge claims and these knowledge claims seldom have evidential support. Examples of work, energy and electromagnetism knowledge claims are: "When you have alot of energy you can run farther or faster" (Zitzewitz, 2002, p.197) and "An electric current is generated in a wire only when the wire cuts magnetic field lines" (Zitzewitz, 2002, p.516).

I chose to teach the work and energy outcomes using textbook based instruction. The S4 physics curriculum outcomes addressed were:

S4P-1-25	Define work as the product of displacement and the component of force parallel to the displacement when the force is constant.
S4P-1-26	Determine work from the area under the force-position graph for any force.
S4P-1-27	Describe work as a transfer of energy. Include: positive and negative work, kinetic energy, conservation of energy
S4P-1-28	Give examples of various forms of energy and describe qualitatively the means by which they can perform work.
S4P-1-29	Derive the equation for kinetic energy using Work =$\mathbf{Fd}\cos\theta$ and kinematic equations. (Manitoba Education and Training, 2005)

I developed two textbook lessons using the Manitoba Education and Training recommended textbook: Zitzewitz, Paul W. (2002). *Physics: Principles and Problems*. New York, NY: Glencoe/McGraw-Hill. The lessons required two days of teaching with each class 1.5 hours in duration. Each lesson followed the Hunter Model of lesson planning, a traditional approach to lesson planning that fits well with the textbook. The lessons included the following: an anticipatory set, stated objectives, modeled practice, guided practice, independent practice, and closure to the lesson.

4.5.1 Non-Contextual Teaching Strategy Lesson 1

Lesson 1 addressed the following curriculum outcomes:

S4P-1-25 Define work as the product of displacement and the component of force parallel to the displacement when the force is constant.

S4P-1-26 Determine work from the area under the force-position graph for any force.

S4P-1-27 Describe work as a transfer of energy. Include: positive and negative work, kinetic energy, conservation of energy.

(Manitoba Education and Training, 2005)

The lesson began with a knowledge activation activity, rotational graffiti, in order to get the students thinking about the concept of work. A series of write-draw questions were written on the tops of pieces of chart paper and each group of students wrote their responses in different colors, one color per group of students. The questions the groups of students wrote or drew about were the following:

Write what you know about energy.

Write what you know about force.

Draw things you push or pull.

The students presented their rotational graffiti to the class which served to inform me about their current understanding of the concepts that would be studied in the work unit (Appendix H). After the rotational graffiti activity students were asked to write down any questions they had related to the activity on their question recording sheet.

4.5.1.1 Anticipatory Set

To get the students interested in the concept of work and energy the following introductory paragraph was read from the textbook.

> "If you spend the morning lifting crates from the floor of a warehouse up onto a truck, you will get tired and hungry. You will need to eat food to "get more energy". Somehow, the energy in the food and it will be transferred into the energy in the raised crates. We use the word work to indicate the amount of energy that was transferred from food to you to the crates. The word work has both an everyday and a scientific meaning. In the case of lifting crates, everyone will agree that work was done. In everyday life, however, we use the word when talking about other activities. For example, everyone says that learning physics is hard work! But in physics, we reserve the term work to mean a very special form of physical activity." (Zitzewitz, 2002, p.198)

It was important for students to realize that work is done on an object only if the object moves so I asked the following textbook question. If you hold a heavy box at the same height for an hour is work done? After having heard responses from the students the following answer was provided.

> "Even if you carry the box at constant velocity and at a constant height, you do no work on it. The force you exert is upward while the motion is sideways, so the box gains no energy. Work is only done when the force and displacement are in the same direction." (Zitzewitz, 2002, p.198)

4.5.1.2 Stated Objectives

Students were told that the definition of work is the product of the force exerted on an object and the distance the object moves in the direction of the force. The mathematical definition was given as W=**Fd**, where **F**=force measured in Newtons, **d**=displacement measured in metres and W=work(a scalar quantity) measured in Newton metres or joules or kgm^2/s^2. The SI unit of work was defined as the joule and students were told the unit was named after James Prescott Joule. The next objective presented to students was the concept that the area under a force-displacement graph is work.

4.5.1.3 Modeled Practice

I modeled the example problem on page 199 of the textbook and demonstrated how to use the formula to calculate work and how to use the graph to also calculate the work.

4.5.1.4 Guided Practice

I gave the students another similar problem to ensure they understood how to perform the calculations. Remediation was given if any students required assistance. After the guided practice activity the students were asked once again to write down any questions they had related to the textbook instruction on their question recording sheet.

4.5.1.5 Independent Practice

The practice problems on page 199 of the textbook were assigned and students independently practiced by themselves. After the independent practice activity the students were asked once again to write down any questions they had related to textbook instruction on their question recording sheet.

4.5.1.6 Closure

The practice problems were corrected bringing closure to the lesson.

At the end of lesson 1, the students recorded in their student journals their attitudes to the method of the instructional delivery. They were asked to answer the prompting questions:

1) What did you like?

2) What did you not like?

3) Comment on the way the lesson was presented.

4) Comment on your level of your engagement.

5) Comment on how the lesson interested you.

4.5.2 Non-Contextual Teaching Strategy Lesson 2

Lesson 2 addressed the following curriculum outcomes:

S4P-1-28 Give examples of various forms of energy and describe qualitatively the means by which they can perform work.

S4P-1-29 Derive the equation for kinetic energy using Work =**Fd**cosθ and kinematic equations. (Manitoba Education and Training, 2005)

4.5.2.1 Anticipatory Set

To get the students interested in the concept of work and direction of force, and to create a sense of anticipation a demonstration was performed. A textbook was pulled at an angle using a Newton scale. The students were asked to predict what component of the force must be used to calculate work if they could recall that work is the product of the force exerted on an object and the distance the object moves in the same direction of the force. The students were able to indicate that the component of force must be the horizontal component or the product of the force and the cosine of the angle between the applied force and the displacement.

The textbook uses the example of pushing a lawnmower to describe work and direction of force and I read the description on page 200 of the textbook and drew the vector diagram describing the handle of the lawnmower and the components of the force. If a force is applied to the lawnmower at an angle, the net force doing the work is the component that acts in the direction of the motion.

4.5.2.2 Stated Objectives

To define the work done when a force is applied at an angle to a motion as being equal to the component of the force in the direction of the motion times the distance moved. The magnitude of the component of the force **F** acting in the direction of motion is found by multiplying the force **F** by the cosine of the angle between **F** and the direction of motion. Work=W=$\mathbf{F}(\cos\theta)\mathbf{d}=\mathbf{F}\mathbf{d}\cos\theta$.

4.5.2.3 Modeled Practice

I modeled the example problem on page 201 of the textbook.

4.5.2.4 Guided Practice

I gave the students another similar problem and ensured they understood how to perform the calculations. Remediation was given to any students who required assistance.

4.5.2.5 Independent Practice

The practice problems on page 202 of the textbook was assigned and students independently practiced by themselves. After the independent practice activity the students wrote down any questions they had related to the textbook instruction on their question recording sheet.

4.5.2.6 Closure

The practice problems were corrected bringing closure to the lesson.

At the end of lesson 2, students recorded in their student journals their attitudes to the method of the instructional delivery. They were asked to answer the prompting questions:

1) What did you like?

2) What did you not like?

3) Comment on the way the lesson was presented.

4) Comment on your level of your engagement.

5) Comment on how the lesson interested you.

A final unit test was given to check for student understanding (Appendix L). The questions came from the end of chapter problems and these questions tested for the concepts presented in both lesson 1 and 2 of the textbook lessons. The questions were from page 213 of the textbook and the selected problems were 1,7,9&10.

4.6 Contextual Teaching Strategy

I developed a hands on activity where students built an electric guitar pickup and an electric guitar. The guitar and the pickup serve as the context through which students learned about electromagnetism. Since students find the concept of electromagnetism very abstract and challenging I developed a series of innovative lessons to make electromagnetism easier to understand. The goal of these lessons is to engage S4 physics students in hands on activities to develop a meaningful understanding of the difficult concept of electromagnetism. The history of the invention of the electric guitar and the electric guitar pickup is a story rich with colorful inventors. Students are personally connected and interested in music and the invention of the electric guitar should stimulate their interest and provide the context and motivation to study electromagnetism. The motivating contextual activities will naturally flow from the history and key questions about flux, Lenz's Law, and electromagnetic induction are all developed using the electric guitar. As each new concept was introduced I explained the way it linked to the electric guitar.

The curriculum outcomes addressed are from the S4 physics electromagnetic induction topic of the electricity unit and the specific learning outcomes are:

S4P-3-7 Define magnetic flux $\Phi=\mathbf{B}A\cos\theta$

S4P-3-8 Demonstrate how a change in magnetic flux induces voltage.

S4P-3-9 Calculate the magnitude of the induced voltage in coils using $V=N\Delta\Phi/\Delta t$

S4P-3-10 Outline Lenz's Law and apply to related problems

(Manitoba Education and Training, 2005)

The contextual teaching strategy consisted of six days of lessons each seventy five minutes in duration culminating in the students making an electric guitar pickup and an electric guitar. Each lesson included a Power Point presentation with the curriculum content and I have included these as appendices. Students were asked to write down questions they had after the instructional strategies were presented for these lessons. These questions were then compared to the questions generated in the non-contextual textbook lessons in an attempt to gauge the degree to which students were engaged differently by the different instructional strategies. To record student attitudes and engagement, a combination of student journals and exit slips were employed to collect additional evidence.

4.6.1 Contextual Teaching Strategy Lesson 1

Lesson 1 began with a rotational graffiti activity to check for prior student understanding by asking students to write and draw about their current conception of musical instruments and electricity. A series of write-draw questions were written on the top of pieces of chart paper and each group of students wrote their responses in different colors, one colour per group of students. The questions the groups of students wrote or drew about are the following:

Write- What role does music play in your life?

Draw- What role does music play in your life?

Write- How do musical instruments work?

Draw- How do musical instruments work?

Write- Where do you find electricity and magnetism in your daily life?

Write- Explain about electricity and magnetism?

Draw- Explain about electricity and magnetism?

The presented their rotational graffiti to the class which served to inform me about their current understanding of the concepts that were studied in the electromagnetism unit (Appendix I). After the rotational graffiti activity students were asked to write down any questions they had related to the activity on their question recording sheet.

A PowerPoint presentation about the history and the invention of the electric guitar (Appendix N) was the next activity. This presentation answered in detail why the electric guitar was invented and introduced the story of its invention. The electric guitar was invented to solve the problem of volume since acoustic guitars could not be heard in big band situations. The quest for louder volume led to a series of design innovations finally culminating in the invention of the electric guitar pickup. The presentation made students aware that the electric guitar pickup uses many principles of electromagnetism and it is these principles that were be studied in the subsequent lessons. After the history of the electric guitar presentation students were asked to write down any questions they had related to the activity on the provided question recording sheets.

The first experimental activity was an iron filings and compass lab and students were given the opportunity to investigate the invisible magnetic field lines of ordinary bar magnets (Appendix O). Since a guitar pickup also has magnets with invisible magnetic field lines, it is important that students investigate these magnetic properties which are similar to guitar pickup magnets. Students sprinkled iron filings on a series of different magnets and combinations of magnets to learn about magnetic field lines, see Figure 1 and 2. I presented a culminating activity where I drew the correct field lines for each combination of magnets.

After the iron filings activity students were asked to write down any questions they had related to the activity on the provided question recording sheets. At the end of lesson1, students recorded in their student journals their attitudes to the method of the instructional delivery. They were asked to answer the prompting questions:

1) What did you like?

2) What did you not like?

3) Comment on the way the lesson was presented.

4) Comment on your level of your engagement.

5) Comment on how the lesson interested you.

Figure 1: Iron Filings Lab

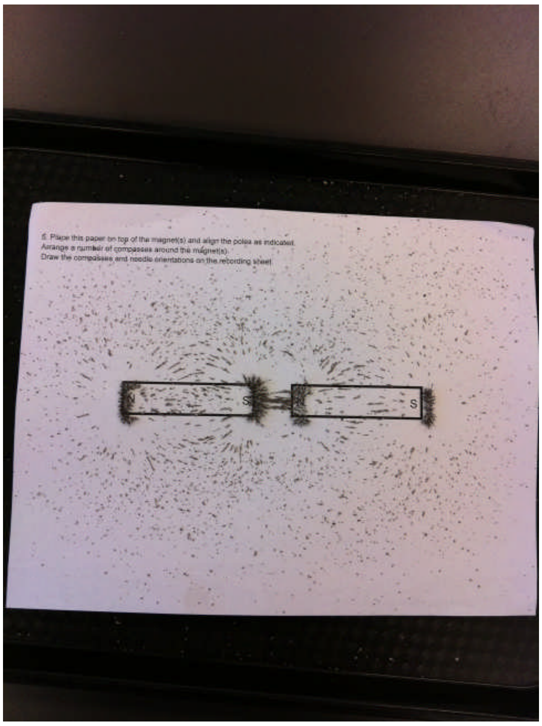


Figure 2: Iron Filings Lab Using Compasses

4.6.2 Contextual Teaching Strategy Lesson 2

I presented a power point about magnetism, (Appendix P) and then modeled three demonstrations that students tried for themselves. The first demonstration involved the movement of a magnet to generate a current in a coil and this is similar to how a guitar string is able to generate a current in the coil of a guitar pickup. The second demonstration illustrated that current and motion are related by showing that a conductor in the presence of a magnetic field is deflected when a current passes through it. This illustrated the opposite of the first demo where the motion of a magnet led to a current since now current plus a magnet now leads to a motion or force. The third demonstration illustrated that electricity and magnetism are related since a current carrying conductor reveals the presence of a magnetic field by the orientation of compasses which is similar to the orientation of compasses around a bar magnet.

4.6.2.1 Demonstration 1: Magnet + Motion = Electricity

A magnet pushed in and out of a coil produces electricity.

Figure 3: Lesson 2 Demo 1

4.6.2.2 Demonstration 2: Electricity + Magnet = Motion

Aluminum wire between the poles of a magnet gives a deflection or force or motion. (F=BIL, formula related to the demonstration). An example using this principle is the speaker, see Figure 4.

Figure 4: Lesson 2 Demo 2

4.6.2.3 Demonstration 3: Magnetic Field Around A Current Carrying Conductor

A current carrying wire produces a magnetic field in loops around the wire, see Figure 5.

Figure 5: Lesson 2 Demo 3

After the demonstrations were presented three stations were set up where students could try these demonstrations themselves. When the students completed the demos they were asked to write down any questions they had related to the instructional activity on their question recording sheet.

At the end of lesson 2, students recorded in their student journals their attitudes to the method of the instructional delivery. They were asked to answer the prompting questions:

1) What did you like?

2) What did you not like?

3) Comment on the way the lesson was presented.

4) Comment on your level of your engagement.

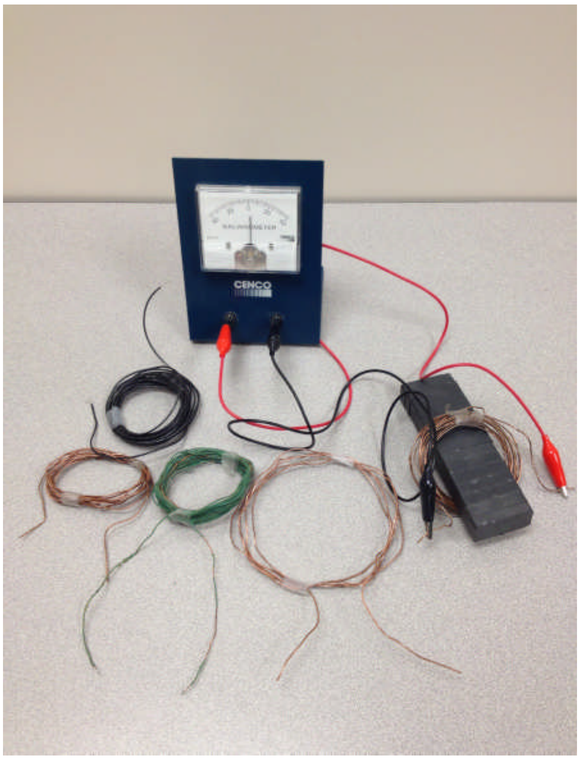
5) Comment on how the lesson interested you.

4.6.3 Contextual Teaching Strategy Lesson 3

Lesson 3 began with a power point presentation about the theory of magnetic flux, (Appendix Q). The first iron filings lab (Lesson 1), where students drew these flux lines was given a mathematical representation through magnetic flux. Magnetic flux is essentially a way of representing the number of magnetic field lines around a bar magnet. I modeled the example magnetic flux problem on the board and then students worked on practice problems based on the magnetic flux formula. Magnetic flux is important in the electric guitar pickup since the movement of the guitar string is responsible for changing the flux with respect to time through the coil of the guitar pickup thereby inducing a current in the pickup. At the end of the lesson students handed in an exit slip of a mathematical problem involving magnetic flux to check for student understanding.

A power point about induced electromotive force (Appendix R) was presented and after the presentation students were asked to record any questions they had related to the presentation on the question recording sheet. Serway (1990) defines an EMF in the following way, "An electromotive force, EMF, is defined as a battery or any other device that provides electrical energy." (p.756). An EMF demonstration was modelled which involved generating a current in a coil of wire by moving a bar magnet into and out of the coil of wire and by generating the same current by changing the coil area. A number of student work stations were set up in the lab where students could try this demonstration themselves to promote further engagement, the apparatus can be seen in Figure 6. When the students completed the EMF demo they were asked to write down any questions they had related to the instructional activity on their question recording sheet.

Figure 6: EMF Demonstration Apparatus



At the end of lesson 3, students recorded their responses to the following prompting questions:

1) What did you like?

2) What did you not like?

3) Comment on the way the lesson was presented.

4) Comment on your level of your engagement.

5) Comment on how the lesson interested you.

4.6.4 Contextual Teaching Strategy Lesson 4

Lesson 4 began with a power point presentation about Faraday's Law of Electromagnetic Induction, (Appendix S). This law brings together, in a mathematical formula, the concepts of magnetism, flux and voltage. Students were told that the concepts we have been studying earlier are coming together and have been elegantly expressed in a mathematical expression where induced voltage is equal to the time rate of change of magnetic flux.

A power point of Lenz's Law was presented next, (Appendix T). After the presentation I modeled an example problem on the board about how to determine the polarity of an induced EMF and then students practiced problems. To check for student understanding I had students hand in an exit slip about determining the polarity of an induced EMF.

The last lesson was a power point describing how the electric guitar pickup works, (Appendix U). In this power point all the concepts that were presented in previous lessons were described with respect to their place within the guitar pickup. After the presentation students were asked to write down on their question recording sheet any questions they had related to the physics of the electric guitar pickup instructional activity.

At the end of lesson 4, students recorded in their student journals their attitudes to the method of the instructional delivery. They were asked to answer the prompting questions:

1) What did you like?

2) What did you not like?

3) Comment on the way the lesson was presented.

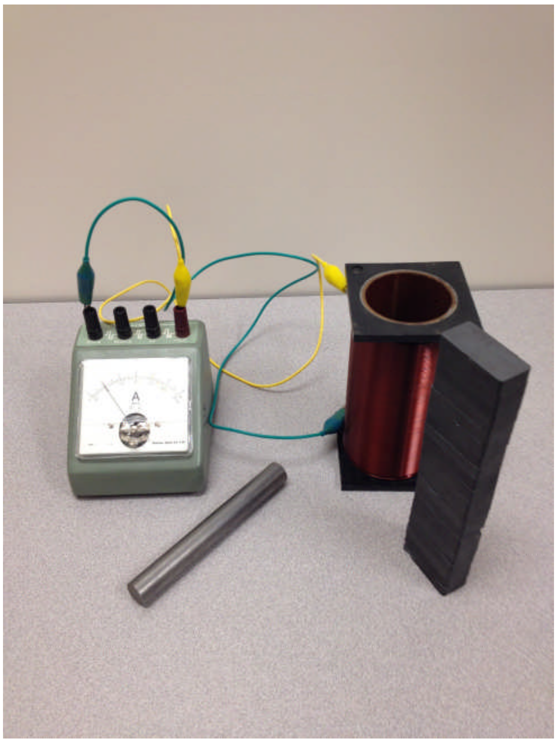
4) Comment on your level of your engagement.

5) Comment on how the lesson interested you.

4.6.5 Contextual Teaching Strategy Lesson 5

Before the students built a guitar pickup I demonstrated how the pickup works using a solenoid, ceramic magnets, ammeter, and a steel rod. This is equipment that students have already used during Lesson 3 where they generated an induced emf using the same apparatus. Since a guitar pickup has 6 small magnets with a coil of wire wrapped around them, the solenoid was used to model the coil of wire and the large ceramic magnets were used to model an individual magnet under a guitar string. In an electric guitar a ferromagnetic string sits above a pickup magnet and the movement of the string generates an induced EMF in the coil around the magnet. To model the electric guitar string an iron rod was used and to model the movement of the guitar string the metal rod was moved from side to side a small distance above the magnets in the solenoid, see Figure 7.

Figure 7: Apparatus Used to Model the Electric Guitar Pickup



To begin the demonstration a solenoid was attached to a galvanometer and a metal rod was moved above a solenoid revealing no deflection of the ammeter needle, see Figure 8. I explained that the movement of the rod is just like the movement of a guitar string and I asked the students the question, "What has to be done so that the needle of the ammeter deflects?", and I discussed any answers students gave. One solution is to make the metal bar magnetic, but if the metal bar represents an electric guitar string then how could the string be made magnetic? The solution is to put a magnet inside the solenoid. Next put the magnets into the solenoid and once again moved the metal bar a small distance above the solenoid. I directed student attention to the ammeter where the needle of the ammeter could be seen to clearly deflect, see Figure 9. Since a small portion of the metal bar directly above the bar magnets becomes slightly magnetic by the solenoid magnet it drags the flux lines with it as it moves. Since the flux is changing with respect to time, by Faraday's law of electromagnetic induction, there must be an induced current in the solenoid which deflects the ammeter needle.

Figure 8: No Deflection of the Ammeter Needle

Figure 9: Deflection of the Ammeter Needle With Magnets in the Solenoid

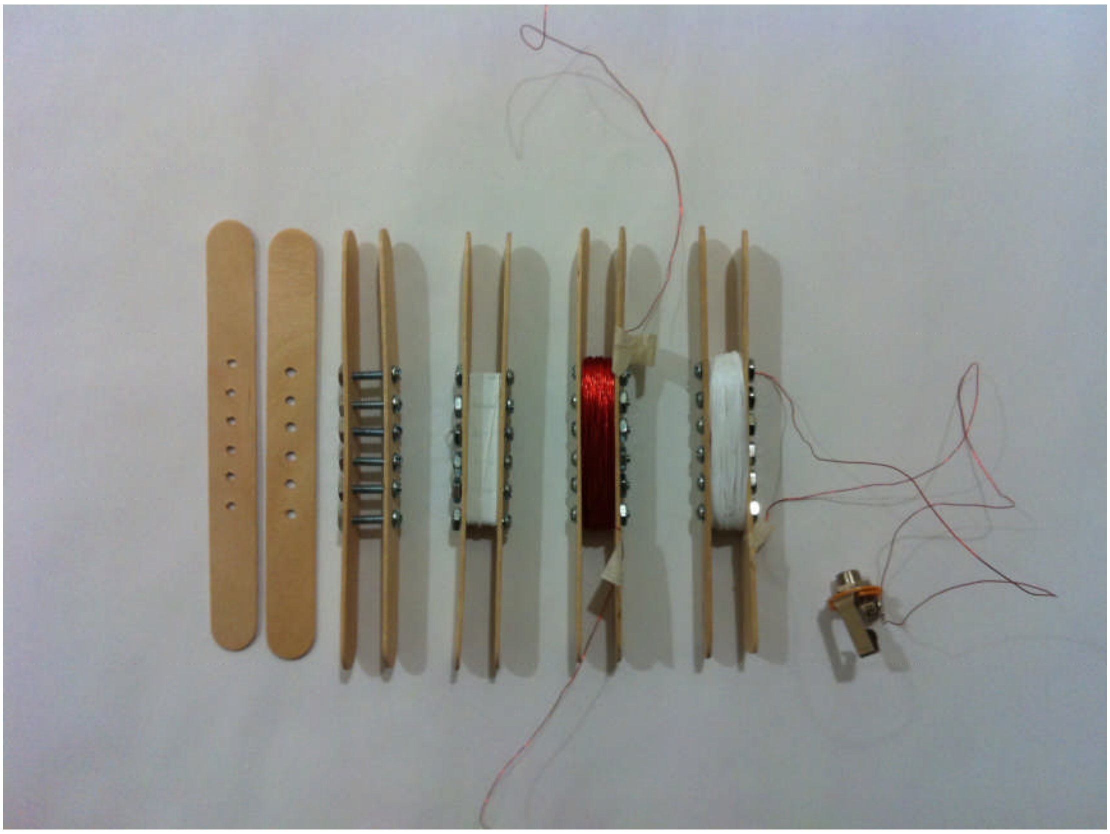
Students built the guitar pickup and were given the necessary materials for the construction of both the electric guitar pickup and the electric guitar see Figure 10. Each group of students was given the construction materials in a small plastic kit, see Figure 11. I modeled the essentials of the construction and then students working in small groups began constructing the pickup, (Appendix V).

Figure 10: Materials Used for the Construction of the Guitar and Pickup

Figure 11: The Student Guitar and Pickup Kit

The tongue depressors that hold the screws of the pickup are pre-drilled and students began by attaching the two tongue depressors together with the screws. Once the two tongue depressors were held by the screws the magnet wire could be wound onto the screws of the pickup. I soldered the ¼” jack onto the pickup in the interest of time and safety. The progression of the pickup construction can be seen in Figure 12.

Figure 12: Stages of the Guitar Pickup Construction



After the students built their electric guitar pickup they were asked to write down any questions they had related to the guitar pickup instructional activity on their question recording sheet. At the end of lesson 5, students recorded in their student journals their attitudes to the method of the instructional delivery. They were asked to answer the prompting questions:

1) What did you like?

2) What did you not like?

3) Comment on the way the lesson was presented.

4) Comment on your level of your engagement.

5) Comment on how the lesson interested you.

4.6.6 Contextual Teaching Strategy Lesson 6

Students built their own guitar during this lesson, (Appendix W) and began construction after I described how the construction should progress. The idea of using the 2x4 for the guitar body and the coke bottle for the guitar bridge came from the movie "It Might Get Loud" a documentary film by filmmaker Davis Guggenheim which featured guitarists Jack White, Jimmy Page and the Edge. At the beginning of the film Jack White builds a one string guitar from a piece of old wood and a coke bottle. After he nails a guitar pickup under the guitar string he plugs the guitar into an amplifier, plays it and then says "Who said you needed to buy a guitar? " (Guggenheim, 2009). This is where I got the inspiration for the guitar design the students built during this lesson. Figure 13 illustrates the different stages of the construction of the electric guitar.

Once the guitar was made the pickup was plugged into an amplifier and the students put the pickup under the string of their guitar. The pickup and guitar construction was tested by plucking the string and listening for the sound produced in the amplifier speaker, see Figure 14.

Figure 13: The Stages of the Guitar Construction

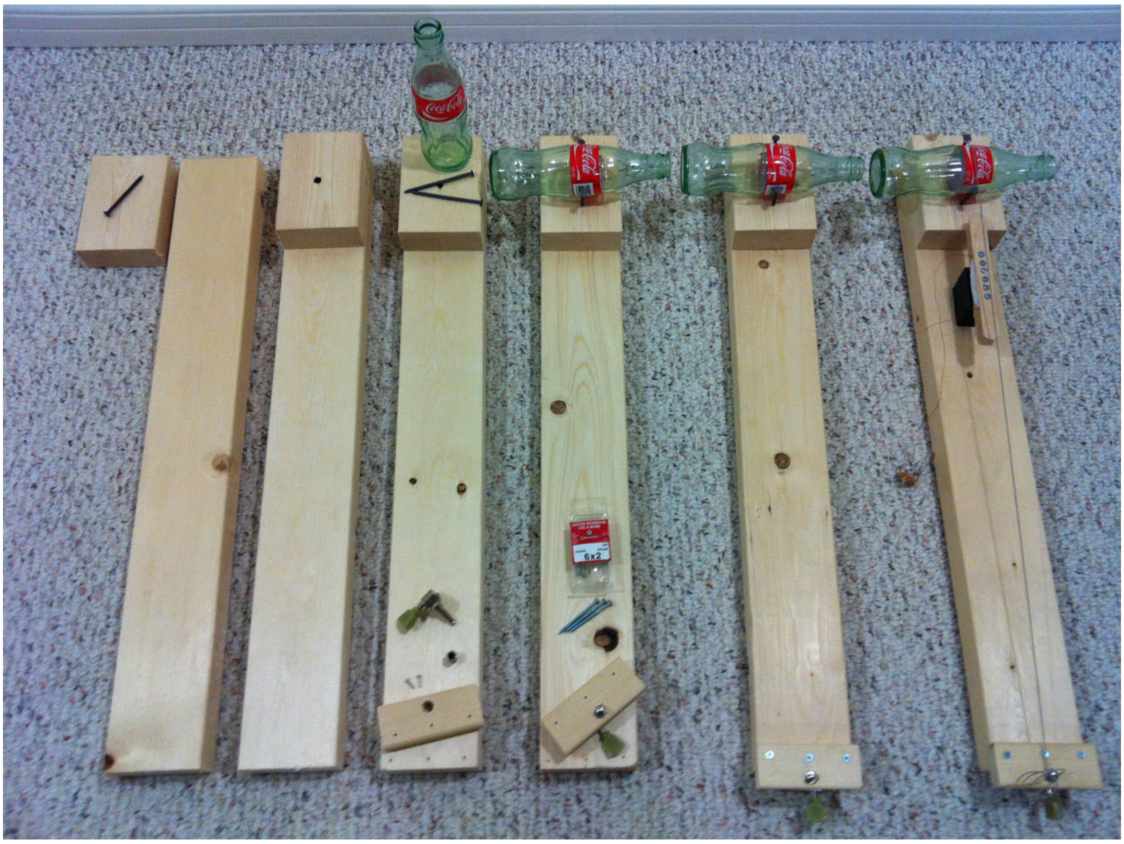
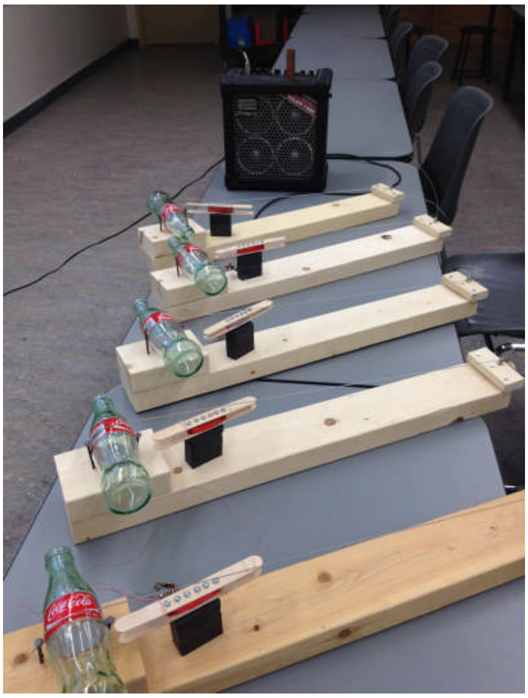


Figure 14: Testing Student Built Guitars and Pickups



Student groups presented their pickup and electric guitar to the class and explained how the pickup worked relating all concepts learned in the unit. Students discussed the success of their pickup and guitar construction. Things like volume and clarity of tone were analyzed and differences were related to such factors as the number of windings of wire in the pickup and the degree of winding tightness. After the students built their electric guitar they were asked to write down any questions they had related to the construction of the electric guitar instructional activity on their question recording sheet.

At the end of lesson 6, students recorded in their student journals their attitudes to the method of the instructional delivery. They were asked to answer the prompting questions:

1) What did you like?

2)What did you not like?

3) Comment on the way the lesson was presented.

4) Comment on your level of your engagement.

5) Comment on how the lesson interested you.

A final unit test was given to check for student understanding (Appendix M). The test included all of the material covered during the electromagnetism lessons.

4.7 Data Analysis

Data about student engagement and attitudes was collected from student generated questions, rotational graffiti, exit slips, final unit assessments, and student journals. The student journals and the teacher journal helped to provide data triangulation for identifying themes about student attitudes while the student generated questions and student journals helped to triangulate data about student engagement.

There were eleven opportunities for students to generate questions from the eight lessons and the degree of student engagement and depth of thought through their question asking required a categorization and ranking scheme. Klassen et al (2011), suggest the following:

> The framework is designed to facilitate the identification of eight distinct categories of student questions in the science classroom. Student questions were rated according to the framework and coded by category. For the sake of scoring and analysis, we assume the underlying construct to be continuous and quantitative. To facilitate the interpretation of the rating data, it must be mapped onto a ranking grid in order to provide numerical values that can be interpreted statistically. (p.10)

The student generated questions were used as an indicator of student intellectual engagement and the questions were ranked according to Klassen et al. (2011). The peripheral questions are at the lowest level and wholly unrelated to either the instructional context or concepts. The factual questions indicate engagement with the instructional concepts at the simplest level and the conceptual questions relate to scientific explanation, clarification, hypothesizing, and testing. Finally, the philosophical questions indicate the highest level of thinking and, certainly, that critical thinking is at work. Once the question data was collected, scoring values were assigned to the framework categories so that engagement could statistically analyzed. (Klassen et al., 2011, pg.11).

Table 1: Scoring Values Assigned to Framework Categories

	Peripheral	Factual	Conceptual	Philosophical
Level 1	P1: 0	F1: 1	C1: 3	E1: 3
Level 2	P2: 2	F2: 2	C2: 4	E2: 5

I categorized and coded the student journals looking for key words where students stated that they enjoyed an activity and where they indicated that they had understood a physics concept. Engagement and comprehension were the themes that the journals were coded for. When a group of students indicated that they liked an activity I looked at my teacher journal to see what activity I was doing at that moment in the class and how engaged students were. Based on their performance on an exit slip or the unit test , I could also determine whether this engagement lead to greater understanding of concepts.

The final unit assessments and the exit slips provided data about student comprehension. From these activities I determined whether the students understood a concept or not. If there was a question on the final unit test that many students got wrong, I tried to determine what day the concept was taught. This provided a reason for the lack of comprehension and whether it could be attributed to a lack of engagement. I could also refer to the student journals since they could give insight into this problem as well. Once the data sources were coded for the themes of comprehension and engagement I made a table indicating what activities lead to greatest comprehension to see if the data correlated to how engaged the students were for that particular activity. A summary of all lesson activities and collected data has been organized into a table, see Table 2.

Table 2: Summary of Lesson Activities and Collected Data

Lesson 1	Lesson2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8
Non-Contextual Teaching Lesson One **ncL1**	Non-Contextual Teaching Lesson Two **ncL2**	Contextual Teaching Lesson One **cL1**	Contextual Teaching Lesson Two **cL2**	Contextual Teaching Lesson Three **cL3**	Contextual Teaching Lesson Four **cL4**	Contextual Teaching Lesson Five **cL5**	Contextual Teaching Lesson Six **cL6**
Rotational Graffiti on Work and Energy **RG1**	Textbook lesson on work at an angle	Rotational Graffiti Music/Electricity/ Magnetism **RG2**	Magnetism PowerPoint	Magnetic Flux PowerPoint	Lenz's Law PowerPoint	Guitar Pickup Demonstration	Building Guitar Activity
Questions Data Collected **Q1**	Questions Data Collected **Q3**	Questions Data Collected **Q4**	3 Magnetism Demonstrations and Student Hands-On Activity	Exit Slip Data Collected **E1**	Exit Slip Data Collected **E2**	Building Guitar Pickup Activity	Questions Data Collected **Q11**
Textbook lesson on Work and energy	Journal Data Collected **J2**	History of the Electric Guitar PowerPoint	Questions Data Collected **Q7**	Induced EMF PowerPoint	Faraday's Law PowerPoint	Questions Data Collected **Q10**	Journal Data Collected **J8**
Questions Data Collected **Q2**	Final Test on Non-Contextual Work and Energy Lessons **FT1**	Questions Data Collected **Q5**	Journal Data Collected **J4**	Induced EMF Demonstrations and Student Hands-On Activity	Guitar Pickup PowerPoint	Journal Data Collected **J7**	Final Test on Contextual Electromagnetism Lessons **FT2**
Journal Data Collected **J1**		Iron Filings Activity		Questions Data Collected **Q8**	Questions Data Collected **Q9**		
		Questions Data Collected **Q6**		Journal Data Collected **J5**	Journal Data Collected **J6**		
		Journal Data Collected **J3**					

Key

c = Contextual	**nc** = Non-Contextual
E = Exit Slip	**FT** = Final Test
J = Journal	**L** = Lesson
Q = Question	**RG** = Rotational Graffiti

CHAPTER 5: RESULTS AND DISCUSSION

5.1 Introduction

In this chapter I present the results and the discussion associated with the Research Questions. The chapter is organized so that the four questions are answered sequentially. In Section 5.2 the questions are listed. Section 5.3 addresses Question One; Section 5.4 addresses Question Two; Section 5.5 addresses Question Three; and Section 5.6 addresses Question Four. Finally Section 5.7 summarizes the chapter.

5.2 General Background

The purpose of this study is to answer through classroom based action research the following four questions:

1. How does the engagement of physics students compare when they are taught using a contextual learning strategy as compared to a non-contextual learning strategy?
2. Do physics students prefer the contextual or non-contextual teaching strategy and what attitudes do physics students have about the contextual and non-contextual learning strategies?
3. How does the level of student understanding of work/energy and electromagnetism compare with my previous experience of teaching without using contextual teaching?
4. Is it possible to motivate S4 physics students in a meaningful, contextual learning activity that facilitates a deeper understanding of the concepts of electromagnetism?

5.3 Research Question 1

The first Research Question is: How does the engagement of physics students compare when they are taught using a contextual learning strategy as compared to a non-contextual learning strategy? To answer this question I will compare the engagement data from student journals and the engagement data from student generated questions provided after a series of instructional strategies. The engagement data obtained from the student journals and from the student questions will be compared with the results from the non-contextual and the contextual lessons.

The journal data will be analyzed using a journal engagement data scoring framework which scores student journal engagement responses from zero to four, see Table 3. The journal engagement data is then compared for each of the thirty two individual students and then for each of the eight individual lessons. The journal analysis concludes with a comparison of the journal engagement scores for student class ranking and student gender.

The engagement based upon student generated questions will be analyzed using the scoring framework from Klassen et al., (2011), Table 1. The data obtained will compare the engagement sums for each of the individual scoring framework categories, peripheral, factual, conceptual, and philosophical. The engagement data is then compared for each of the thirty two individual students and then for each of the eleven times question data was collected. The question analysis will then compare the engagement for student class ranking, student gender and finally for the rotational graffiti lessons.

5.3.1 Analysis of Journal Data

5.3.1.1 Analysis of the Journal Data Using the Journal Engagement Scoring Framework

Students wrote in their journals on eight occasions and answered the following five questions:

1) What did you like?

2) What did you not like?

3) Comment on the way the lesson was presented.

4) Comment on your level of your engagement.

5) Comment on how the lesson interested you.

Students were asked these question to provide them with an opportunity to voice their opinion about how they felt about the instructional strategy. In analyzing student engagement for the non-contextual and contextual lessons student responses to question 4, "Comment on your level of engagement.", were analyzed. Student responses were scored from 0 to 4 where a score of 0 represented no engagement while a score of 4 represented the most engagement. Students represented their level of engagement in a descriptive manner rather than providing an engagement number they interpreted from a given scale. The student responses were analyzed looking for descriptive adjectives that corresponded to one of the five possible engagement scores. The descriptive adjectives progressed from negative to positive where a score of 0 used a negative modifier of engagement such as "very little", a score of 1 used a less negative modifier such as "slightly", a score of 2 used a positive modifier such as "more", a score of 3 used a more positive modifier such as "really" and a score of 4 used the most positive modifier such as "extremely". Common responses were grouped based upon the engagement modifier and a scoring framework was developed, see Table 3

Table 3: Journal Engagement Data Scoring Framework

Engagement Score	Similar Student Responses
0	boring, I was not engaged, very little
1	slightly engaged, somewhat engaged, semi-engaged
2	engaged, more engaging
3	very engaged, really engaged
4	extremely engaged, totally engaged, super engaged

The data in Table 4 represents the journal engagement data including the rank and the gender of the students for each of the 32 students and each student was assigned a score of 0,1, 2, 3,or 4. The data has been divided into non-contextual and contextual lessons and students who were not present were given an "absent" in the table. The non-contextual data from Table 4 reveals many more zeros and ones indicating that students were reporting that they were not engaged. The journal responses for the contextual journal entries reveal more two, three, and four engagement scores indicating that students recorded they were more engaged for these lessons.

Table 4: Journal Engagement Data

			non-contextual		**contextual**					
student	**gender**	**rank**	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**
1	F	3	0	0	0	2	3	2	2	2
2	F	3	0	0	absent	absent	1	1	absent	absent
3	M	1	1	0	1	2	2	3	3	3
4	M	1	0	0	2	2	2	3	3	3
5	F	1	0	0	2	absent	2	2	4	2
6	F	1	absent	0	absent	absent	0	absent	0	0
7	F	1	absent	0	3	1	absent	2	3	4
8	M	2	2	2	2	2	2	2	3	2
9	M	2	2	2	2	2	4	4	4	absent
10	M	3	0	0	2	2	2	0	4	3
11	M	1	absent	0	3	2	2	2	3	3
12	M	1	1	1	absent	absent	1	3	4	absent
13	M	2	2	0	absent	absent	absent	2	absent	4
14	M	3	2	absent	absent	absent	absent	absent	3	2
15	M	1	absent	absent	4	2	0	1	3	3
16	F	2	3	0	4	2	2	2	absent	absent
17	F	1	1	0	3	1	3	3	4	4
18	M	1	1	1	4	3	4	4	4	4
19	F	1	0	0	4	3	3	3	4	4
20	M	2	absent	absent	2	2	4	2	2	3
21	F	1	1	0	3	2	3	2	4	3
22	F	1	1	0	absent	absent	2	absent	absent	absent
23	F	3	0	1	1	2	2	2	4	2
24	F	3	1	0	2	1	2	2	3	2
25	F	2	absent	1	2	1	2	absent	absent	absent
26	M	1	absent	absent	4	2	2	4	2	2
27	M	3	2	3	4	0	3	absent	3	3
28	F	1	absent	absent	2	2	2	4	3	3
29	F	2	absent	absent	absent	absent	0	1	3	2
30	F	1	absent	absent	2	absent	0	0	2	0
31	F	3	1	0	0	0	0	0	2	0
32	F	3	1	absent	1	2	1	0	1	1

5.3.1.2 Comparing the Mean Journal Engagement Scores for Individual Students

For each student the engagement score of lessons one and two were averaged to give a mean non-contextual engagement score and the engagement scores of lessons three to eight were averaged to give a mean contextual engagement score, see Table 5. These scores represent the average level of engagement for each student for each of the non-contextual and contextual lessons for comparison purposes. Student data was removed for students who were absent from both non-contextual lessons since then a comparison with their contextual score could not be made, no student was absent for all the contextual lessons. The data for students 15, 20, 26, 28, 29 and 30 were removed leaving the following data in Table 6. Figure 15 represents the mean data for the non-contextual and contextual engagement scores and very often the non-contextual scores were 0 or close to 0 and rarely even came close to the scores of the contextual scores. The graph illustrates that the non-contextual scores never reached the level of the contextual scores. The students, through their own descriptions of their own involvement, were more engaged for the contextual lessons than the non-contextual lessons.

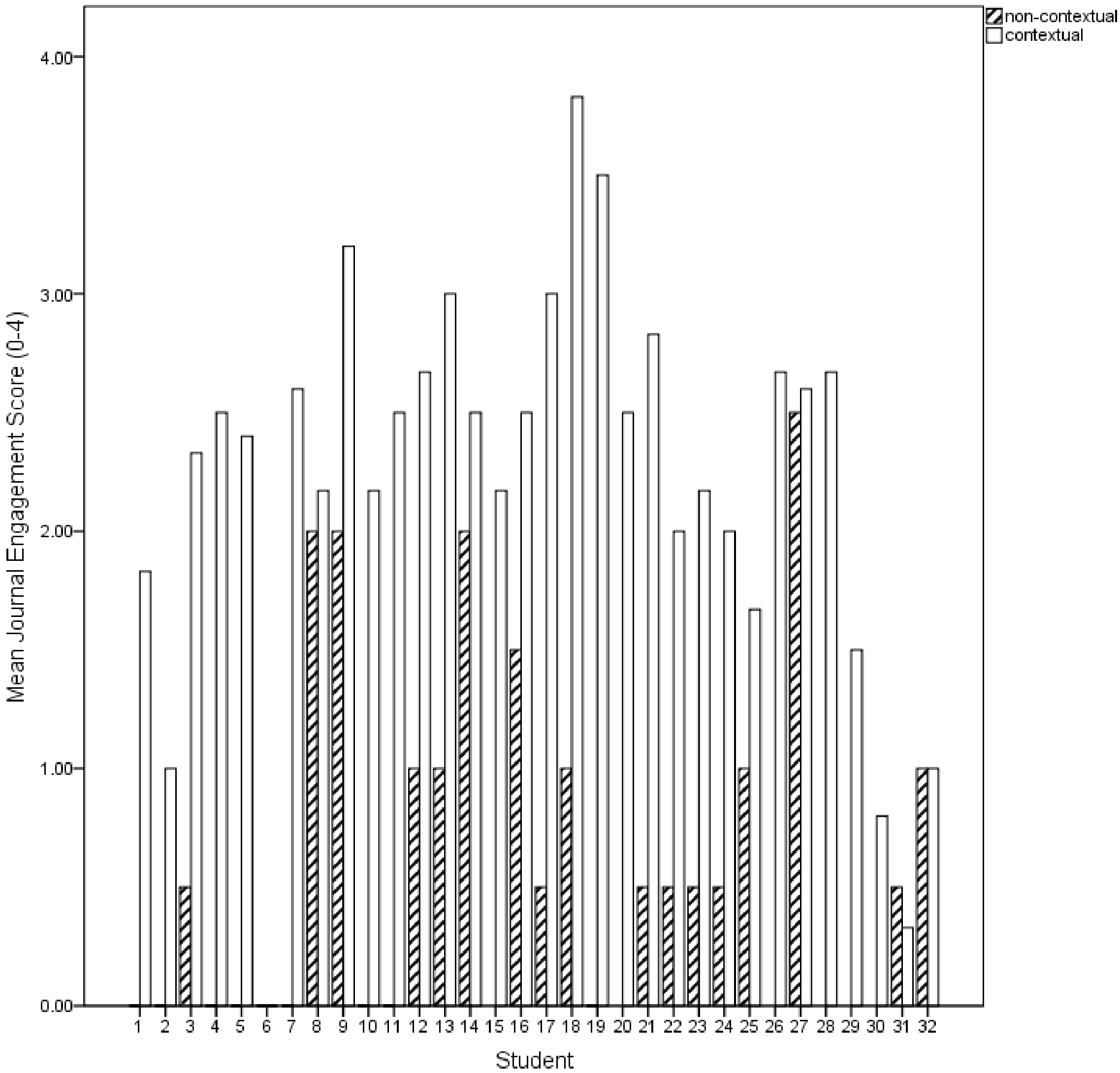
Table 5: Student Journal Engagement Scores With Student Mean Scores

	non-contextual			**contextual**						
student	**J1**	**J2**	**mean**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**	**mean**
1	0	0	**0**	0	2	3	2	2	2	**1.8**
2	0	0	**0**	absent	absent	1	1	absent	absent	**1.0**
3	1	0	**0.5**	1	2	2	3	3	3	**2.3**
4	0	0	**0**	2	2	2	3	3	3	**2.5**
5	0	0	**0**	2	absent	2	2	4	2	**2.4**
6	absent	0	**0**	absent	absent	0	absent	0	0	**0.0**
7	absent	0	**0**	3	1	absent	2	3	4	**2.6**
8	2	2	**2**	2	2	2	2	3	2	**2.2**
9	2	2	**2**	2	2	4	4	4	absent	**3.2**
10	0	0	**0**	2	2	2	0	4	3	**2.2**
11	absent	0	**0**	3	2	2	2	3	3	**2.5**
12	1	1	**1**	absent	absent	1	3	4	absent	**2.7**
13	2	0	**1**	absent	absent	absent	2	absent	4	**3.0**
14	2	absent	**2**	absent	absent	absent	absent	3	2	**2.5**
15	absent	absent	**absent**	4	2	0	1	3	3	**2.2**
16	3	0	**1.5**	4	2	2	2	absent	absent	**2.5**
17	1	0	**0.5**	3	1	3	3	4	4	**3.0**
18	1	1	**1**	4	3	4	4	4	4	**3.8**
19	0	0	**0**	4	3	3	3	4	4	**3.5**
20	absent	absent	**absent**	2	2	4	2	2	3	**2.5**
21	1	0	**0.5**	3	2	3	2	4	3	**2.8**
22	1	0	**0.5**	absent	absent	2	absent	absent	absent	**2.0**
23	0	1	**0.5**	1	2	2	2	4	2	**2.2**
24	1	0	**0.5**	2	1	2	2	3	2	**2.0**
25	absent	1	**1**	2	1	2	absent	absent	absent	**1.7**
26	absent	absent	**absent**	4	2	2	4	2	2	**2.7**
27	2	3	**2.5**	4	0	3	absent	3	3	**2.6**
28	absent	absent	**absent**	2	2	2	4	3	3	**2.7**
29	absent	absent	**absent**	absent	absent	0	1	3	2	**1.5**
30	absent	absent	**absent**	2	absent	0	0	2	0	**0.8**
31	1	0	**0.5**	0	0	0	0	2	0	**0.3**
32	1	absent	**1**	1	2	1	0	1	1	**1.0**

Table 6: Mean Journal Engagement Scores for Non-contextual and Contextual Lessons for Each Student

Student	Non-contextual mean	Contextual mean
1	0	1.8
2	0	1.0
3	0.5	2.3
4	0	2.5
5	0	2.4
6	0	0.0
7	0	2.6
8	2	2.2
9	2	3.2
10	0	2.2
11	0	2.5
12	1	2.7
13	1	3.0
14	2	2.5
16	1.5	2.5
17	0.5	3.0
18	1	3.8
19	0	3.5
21	0.5	2.8
22	0.5	2.0
23	0.5	2.2
24	0.5	2.0
25	1	1.7
27	2.5	2.6
31	0.5	0.3
32	1	1.0
mean	0.7	2.2

Figure 15: Journal Engagement Means for Each Student



Taking the average for all of the individual means for the student means from Table 6 we get a class average engagement score for the non-contextual and contextual lessons. The mean and standard deviation for the contextual engagement scores were ($\overline{x}$ = 2.2, S_d = 0.9, n = 26) and the mean and standard deviation for the non-contextual engagement scores were ($\overline{x}$ = 0.7, S_d = 0.8, n = 26), where $\overline{x}$ = mean and S_d = standard deviation, n = sample size, see Table 7. Since the standard deviations are very similar this indicates that the variability does not change between the non-contextual and contextual means. The variation of student scores is similar but the mean score for the contextual lessons is much higher than the non-contextual lessons.

Table 7: Mean and Standard Deviation for Mean Non-contextual and Contextual Engagement Scores for Each Student

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
contextualjournalengscore	26	.00	3.83	2.2423	.88662
noncontextualjournalengscore	26	.00	2.50	.7115	.75064
Valid N (listwise)	26				

Figure 16 illustrates the class average engagement scores from Table 7 indicating that the contextual lessons produced student engagement scores considerably greater than the non-contextual lessons, see.

Figure 16: Non-contextual and Contextual Lessons Mean Student Engagement Score

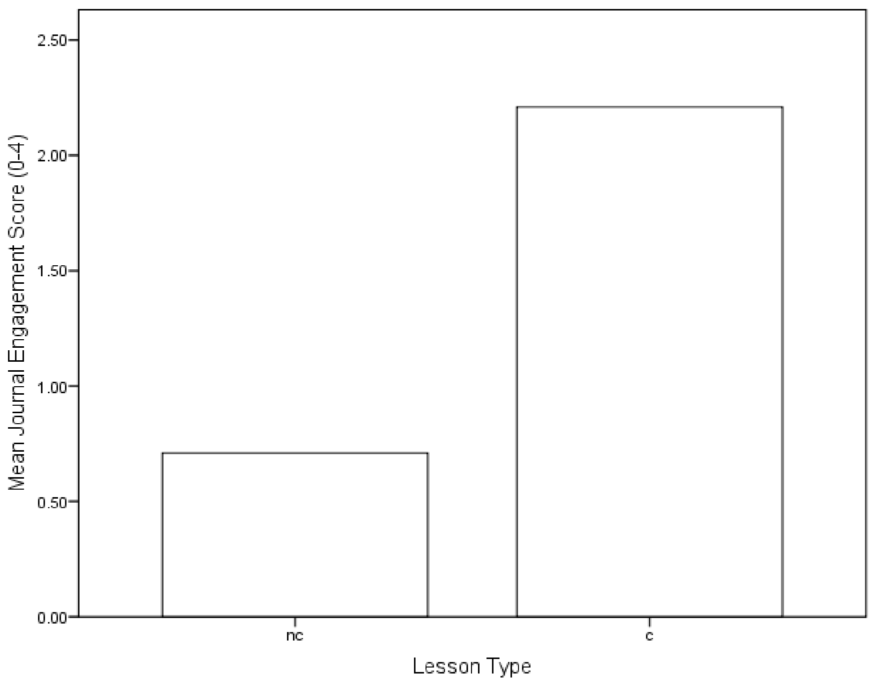


Table 8 represents a paired sample t-test performed on the student mean data to determine if the mean data was statistically significant. In this study 32 students were exposed to non-contextual teaching lessons and contextual teaching lessons and then were given an opportunity to describe how engaged they were by describing their level of engagement in a student journal. The question is whether the engagement differs in the two different lesson delivery methods. Using a paired samples t-test I want to determine if there is a statistically significant difference in the means for the non-contextual engagement scores and the contextual engagement scores. The null hypothesis is Ho: $\mu_d = 0$ and the alternative hypothesis is H_1: $\mu_d \neq 0$, where $\mu_d = \mu_c - \mu_{nc}$ (c = contextual and nc = non-contextual). By conventional criteria, the difference between the contextual and non-contextual mean engagement scores is considered to be extremely statistically significant, $t = 7.7$, $df = 25$, $p\text{-value} < 0.001$.

Table 8: T-test Data for Mean Comparison for Non-contextual and Contextual Journal Engagement Scores

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	contextualjournalengscore - noncontextualjournalengscore	1.53077	1.01438	.19894	1.12105	1.94049	7.695	25	.000

5.3.1.3 Comparing the Mean Journal Engagement Scores for the Individual Lessons

Students wrote about the level of their engagement at the end of every lesson in their student journals and since there were eight lessons there were eight journal entries for each of the thirty two students. How does this engagement data vary from lesson to lesson? The previous data represented the average engagement score for individual student data and the analysis for this section will examine the average engagement score for individual lesson data. Since there were 6 contextual lessons as compared to 2 non-contextual lessons, to determine if the data is skewed for the contextual lessons the average engagement scores for individual lessons were compared. The student engagement scores were averaged to give a mean engagement score for each lesson to determine if one particular lesson was skewing the data and this data can be found at the bottom of Table 9 and summarized in Table 10. The data at the bottom of Table 9 and summarized in Table 10 represents the average journal score for a particular lesson. These eight averages represent how engaged the entire class was for a particular lesson.

When the mean scores were calculated, students who were absent were not used in the mean calculation. The student n-sample size modified for absences and the mean and standard deviation for each lesson can be seen in Table 11. Figure 17 illustrates that the mean student journal engagement scores for the contextual lessons are greater than the mean student journal engagement scores for the non-contextual lessons. The student self reflection in their journals revealed that students were much more engaged in the contextual lessons. Some students who did reflect positively about the non-contextual lessons but they were in a minority.

Table 9: Student Journal Engagement Scores for Each of Eight Lessons

	Non-contextual engagement score		**Contextual engagement score**					
student	**Lesson1**	**Lesson 2**	**Lesson 3**	**Lesson 4**	**Lesson 5**	**Lesson 6**	**Lesson 7**	**Lesson 8**
1	0	0	0	2	3	2	2	2
2	0	0	absent	absent	1	1	absent	absent
3	1	0	1	2	2	3	3	3
4	0	0	2	2	2	3	3	3
5	0	0	2	absent	2	2	4	2
6	absent	0	absent	absent	0	absent	0	0
7	absent	0	3	1	absent	2	3	4
8	2	2	2	2	2	2	3	2
9	2	2	2	2	4	4	4	absent
10	0	0	2	2	2	0	4	3
11	absent	0	3	2	2	2	3	3
12	1	1	absent	absent	1	3	4	absent
13	2	0	absent	absent	absent	2	absent	4
14	2	absent	absent	absent	absent	absent	3	2
15	absent	absent	4	2	0	1	3	3
16	3	0	4	2	2	2	absent	absent
17	1	0	3	1	3	3	4	4
18	1	1	4	3	4	4	4	4
19	0	0	4	3	3	3	4	4
20	absent	absent	2	2	4	2	2	3
21	1	0	3	2	3	2	4	3
22	1	0	absent	absent	2	absent	absent	absent
23	0	1	1	2	2	2	4	2
24	1	0	2	1	2	2	3	2
25	absent	1	2	1	2	absent	absent	absent
26	absent	absent	4	2	2	4	2	2
27	2	3	4	0	3	absent	3	3
28	absent	absent	2	2	2	4	3	3
29	absent	absent	absent	absent	0	1	3	2
30	absent	absent	2	absent	0	0	2	0
31	1	0	0	0	0	0	2	0
32	1	absent	1	2	1	0	1	1
lesson mean	**1.0**	**0.5**	**2.4**	**1.7**	**1.9**	**2.1**	**3.0**	**2.5**

Table 10: Mean Student Journal Engagement Scores for Each Lesson

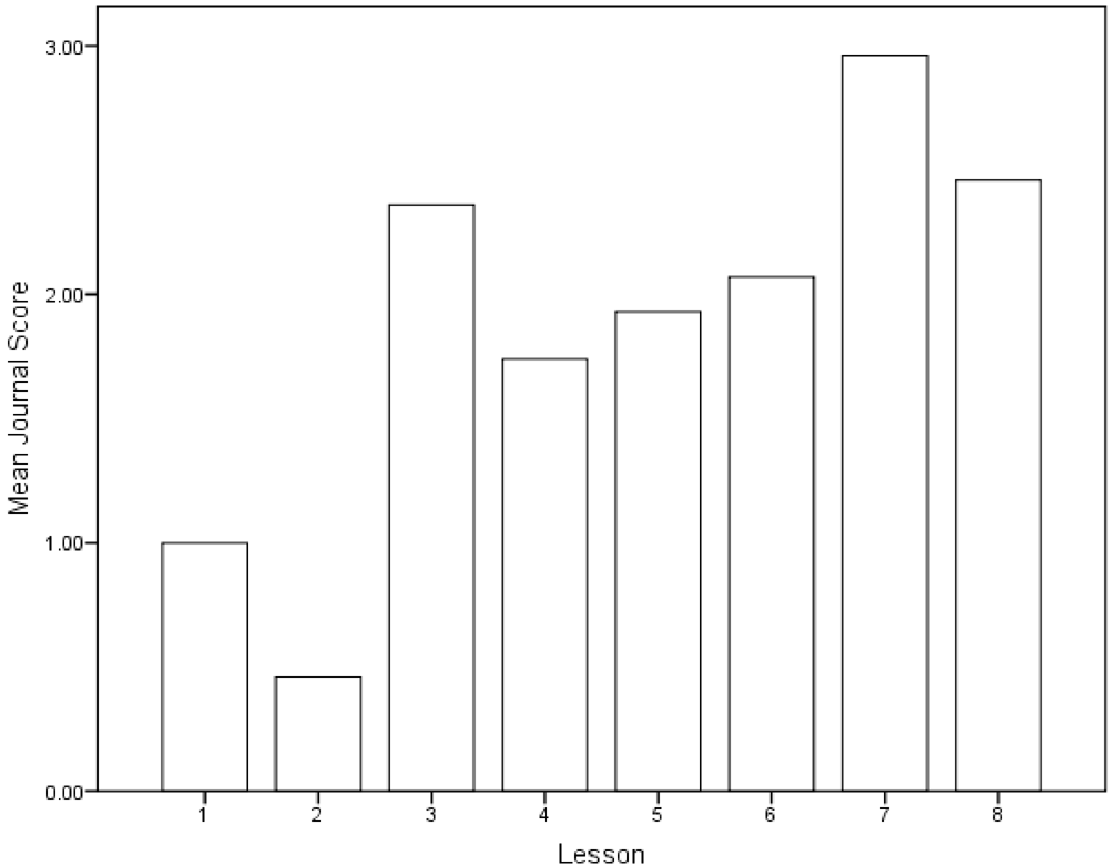
Lesson	**Mean Journal Engagement Score**
1	1.0
2	0.5
3	2.4
4	1.7
5	1.9
6	2.1
7	3.0
8	2.5

Table 11: Mean Journal Student Engagement for Each Lesson Including Standard Deviation and Sample Size

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
l1	22	0	3	1.00	.873
l2	24	0	3	.46	.833
l3	25	0	4	2.36	1.221
l4	23	0	3	1.74	.752
l5	29	0	4	1.93	1.193
l6	27	0	4	2.07	1.238
l7	27	0	4	2.96	1.018
l8	26	0	4	2.46	1.208
Valid N (listwise)	12				

Figure 17: Mean Student Journal Engagement Scores for Each Lesson



Lessons one and two represent the non-contextual lessons and lessons three to eight represent the contextual lessons. The lesson engagement scores for the non-contextual lessons were averaged and the lesson engagement scores from the contextual lessons were averaged in order to get an overall non-contextual lesson score and an overall contextual lesson score. Table 12 represents the mean and standard deviation for student scores for each lesson is: non-contextual ($\overline{x}$ = 0.7, Sd = 0.4, n = 2) and contextual ($\overline{x}$ = 2.3, Sd = 0.4, n = 6), where $\overline{x}$ = mean and Sd = standard deviation, n = sample size. Since the average contextual lessons had an engagement score much greater than the average non-contextual lessons, students indicated in their journals that they were much more engaged during the contextual lessons. The data represented in Figure 18 illustrates the average lesson data indicating that the contextual mean journal engagement score for lessons three to eight is greater than the non-contextual mean score for lessons one and two. The means in Table 12 have similar standard deviations so both the contextual and non-contextual means have about the same variability around these values. The data points are about equally clustered around the contextual and non-contextual means.

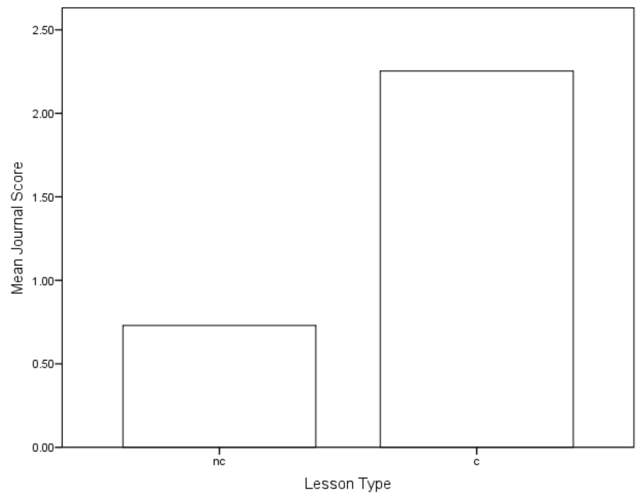
The student engagement scores for the class and the student engagement scores for the lessons indicate that the contextual approach was preferred by the students.

Table 12: Mean Journal Scores for Non-contextual and Contextual Lessons

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
nc	2	.46	1.00	.7300	.38184
c	6	1.74	2.96	2.2533	.43707
Valid N (listwise)	2				

Figure 18: Mean Student Journal Engagement Scores for Non-contextual and Contextual Lessons



5.3.1.4 Analysis of Journal Engagement Data by Class Ranking

When calculating the journal engagement ranking data the class was divided into three ranks based upon the grade the student had in the physics 40S class at the time of the research, see Table 4. A rank of one corresponded to a class grade between 85% & 100%, a rank of two corresponded to a class grade between 67% & 84%, while a rank of 3 corresponded to a class grade between 50% & 66%. Sixteen students had a ranking of one or 50% of the class, seven students had a ranking of two or 22 % of the class and nine students had a ranking of three or 28% of the class. Since some students were absent their data had to be removed when the mean ranking scores were calculated. Students 15, 26, 28 and 30 were removed from the non-contextual rank 1 data and students 20 and 29 were removed from the rank two non-contextual data, see Table 13. Table 13 represents the average score for each of the three student rankings and this data is summarized in Table 14 including the standard deviation and sample size. The mean and standard deviation for the contextual rank one journal engagement scores are ($\bar{x}$ = 2.4, S_d = 0.9, n = 16), the contextual rank two journal engagement scores are ($\bar{x}$ = 2.4, S_d = 0.6, n = 7) and the contextual rank three journal engagement scores are ($\bar{x}$ = 1.7, S_d = 0.8, n = 9). The mean and standard deviation for the non-contextual rank one journal engagement scores are ($\bar{x}$ = 0.3, S_d = 0.9, n = 12), the non-contextual rank two journal engagement scores are ($\bar{x}$ = 1.5, S_d = 0.5, n = 5) and the non-contextual rank three journal engagement scores are ($\bar{x}$ = 0.8, S_d = 0.9, n = 9), where $\bar{x}$ = mean and S_d = standard deviation, n = sample size. The standard deviation for all the data indicates about the same variability around the means.

The data indicates that for the contextual lessons, a student's rank matched with their engagement mean score. The rank one and rank two students had the highest scores followed by the rank three students. The contextual mean journal engagement scores for class rankings one to three were greater than the mean journal engagement scores for non-contextual class rankings one to three. The contextual rank one and rank two scores were about the same but were both greater than the rank three score. The non-contextual rank two journal engagement score was greater than the rank one non-contextual journal engagement score and the rank three non-contextual journal engagement score. For the non-contextual lessons the rank two students had engagement scores greater than both the rank one and the rank three students.

Figure 19 illustrates the mean data for the student ranking. The journal data which was obtained from personal student reflections of their engagement indicates that when comparing student class ranking, students preferred the contextual lessons over the non-contextual lessons.

Table 13: Journal Engagement Data for Class Ranking

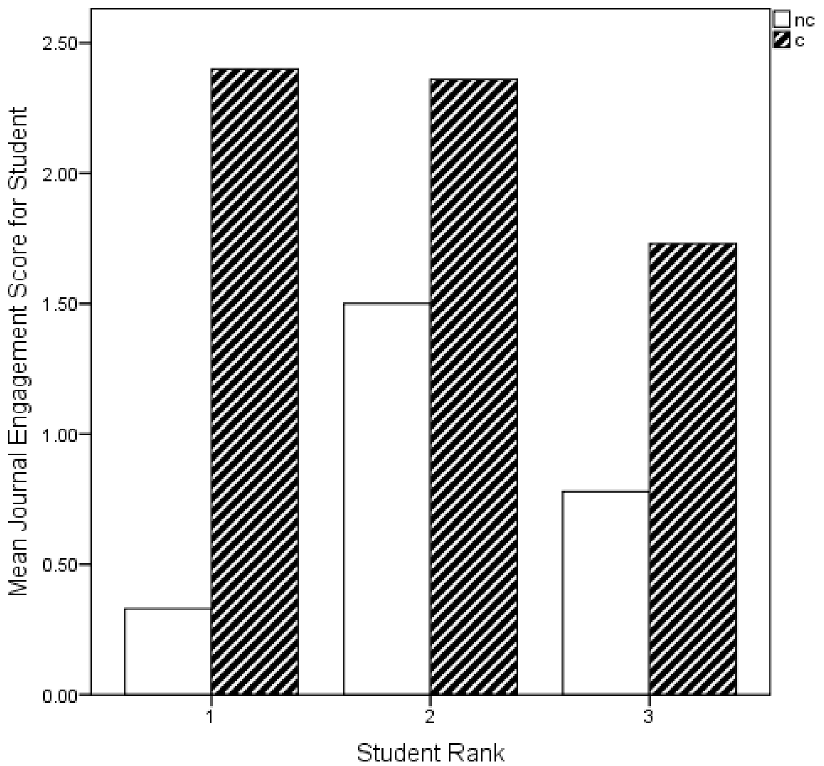
student	rank	Student mean journal engagement score non-contextual	mean rank score	Student mean journal engagement score contextual	mean rank score
3	1	0.5	**0.3**	2.3	**2.4**
4	1	0.0		2.5	
5	1	0.0		2.4	
6	1	0.0		0.0	
7	1	0.0		2.6	
11	1	0.0		2.5	
12	1	1.0		2.7	
15	1	absent		2.2	
17	1	0.5		3.0	
18	1	1.0		3.8	
19	1	0.0		3.5	
21	1	0.5		2.8	
22	1	0.5		2.0	
26	1	absent		2.7	
28	1	absent		2.7	
30	1	absent		0.8	
8	2	2.0	**1.5**	2.2	**2.4**
9	2	2.0		3.2	
13	2	1.0		3.0	
16	2	1.5		2.5	
20	2	absent		2.5	
25	2	1.0		1.7	
29	2	absent		1.5	
1	3	0.0	**0.8**	1.8	**1.7**
2	3	0.0		1.0	
10	3	0.0		2.2	
14	3	2.0		2.5	
23	3	0.5		2.2	
24	3	0.5		2.0	
27	3	2.5		2.6	
31	3	0.5		0.3	
32	3	1.0		1.0	

Table 14: Mean and Standard Deviation for Journal Engagement Data Based on Class Ranking

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
rank1nc	12	.00	1.00	.3333	.38925
rank2nc	5	1.00	2.00	1.5000	.50000
rank3nc	9	.00	2.50	.7778	.90523
rank1c	16	.00	3.83	2.4044	.91710
rank2c	7	1.50	3.20	2.3629	.63326
rank3c	9	.33	2.60	1.7333	.77827
Valid N (listwise)	5				

Figure 19: Mean Journal Engagement Score for Students vs. Class Ranking



5.3.1.5 Analysis of Journal Engagement Data by Gender

To analyze the gender data the 32 student class was divided into females and males. The physics 40S class consisted of 18 females or 56.3% of the class and 14 males or 43.8% of the class, see Table 4. The mean journal engagement scores were averaged for each gender and student data was removed in the mean calculation if the student was absent. Students 28, 29 and 30 were excluded from the non-contextual female mean calculation and students 15, 20 and 26 were excluded from the contextual male mean calculation.

Table 15 illustrates the mean journal engagement score for males and females for the non-contextual and contextual lessons ordered for gender. Table 16 represents the gender mean engagement data including the standard deviation and sample size. The mean and standard deviation for the contextual male data was ($\overline{x}$ = 2.6, S_d = 0.5, n = 14) and for the contextual female data it was ($\overline{x}$ = 1.9, S_d = 1.0, n = 18). The mean and standard deviation for the non-contextual male data was ($\overline{x}$ = 1.1, S_d = 0.9, n = 11) and for the non-contextual female data it was ($\overline{x}$ = 0.4, S_d = 0.5, n = 15), where $\overline{x}$ = mean and S_d = standard deviation, n = sample size. The data indicates that both males and females preferred the contextual lessons. Males obtained scores greater than females for both contextual and non-contextual lessons but female scores were close to male scores for the contextual lessons. Figure 20 illustrates the engagement gender mean scores for the non-contextual and contextual lessons. For both males and females there was a strong preference for the contextual lessons.

Table 15: Mean Non-contextual and Contextual Mean Journal Engagement Scores for Class Gender

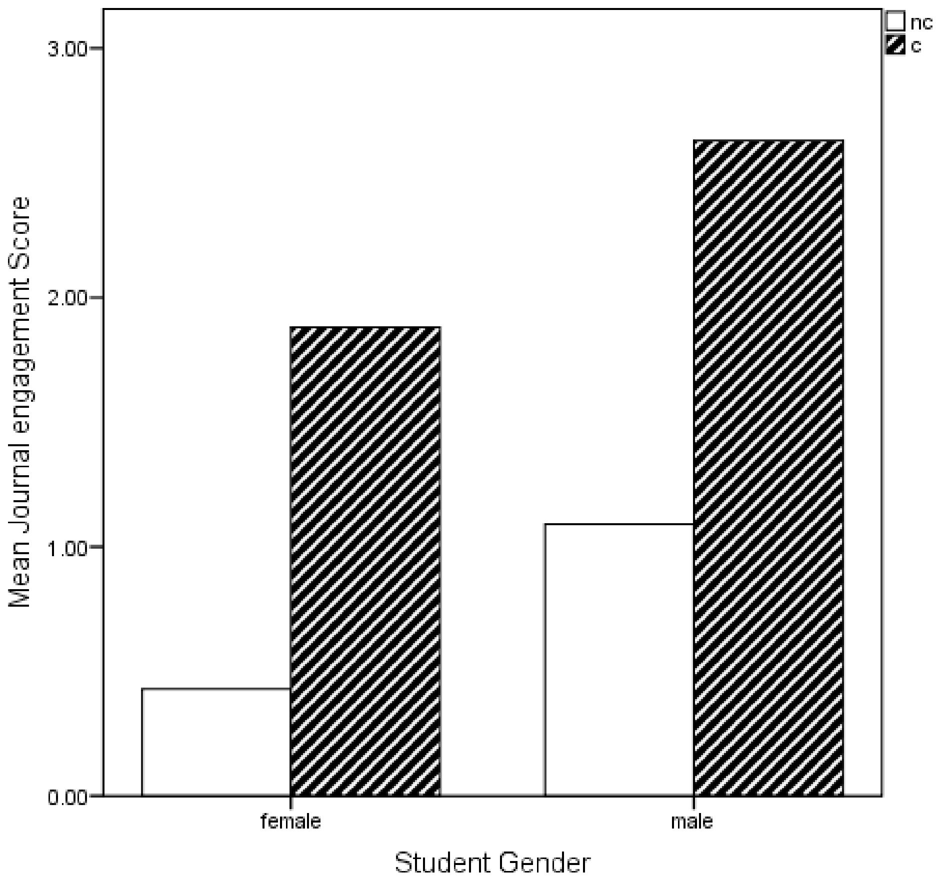
student	gender	Student mean journal engagement score non-contextual	gender mean score	Student mean journal engagement score contextual	gender mean score
1	F	0	**0.4**	1.8	**1.9**
2	F	0		1.0	
5	F	0		2.4	
6	F	0		0.0	
7	F	0		2.6	
16	F	1.5		2.5	
17	F	0.5		3.0	
19	F	0		3.5	
21	F	0.5		2.8	
22	F	0.5		2.0	
23	F	0.5		2.2	
24	F	0.5		2.0	
25	F	1		1.7	
28	F	absent		2.7	
29	F	absent		1.5	
30	F	absent		0.8	
31	F	0.5		0.3	
32	F	1		1.0	
3	M	0.5	**1.1**	2.3	**2.6**
4	M	0		2.5	
8	M	2		2.2	
9	M	2		3.2	
10	M	0		2.2	
11	M	0		2.5	
12	M	1		2.7	
13	M	1		3.0	
14	M	2		2.5	
15	M	absent		2.2	
18	M	1		3.8	
20	M	absent		2.5	
26	M	absent		2.7	
27	M	2.5		2.6	

Table 16: Mean and Standard Deviation for Journal Engagement Scores by Gender

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
femalenc	15	.00	1.50	.4333	.45774
malenc	11	.00	2.50	1.0909	.91701
femalec	18	.00	3.50	1.8778	.95593
malec	14	2.17	3.83	2.6293	.45559
Valid N (listwise)	10				

Figure 20: Mean Journal Engagement Score for Students vs. Student Gender



5.3.2 Analysis of Question Data

5.3.2.1 Analysis of the Engagement Questions Using the Question Ranking Framework

Question data was collected from students on eleven occasions during the course of eight lessons where lessons one and two were non-contextual lessons and lessons three to eight were contextual lessons. During lesson one, questions were collected from students twice and during lesson three questions were collected three times. For the remaining lessons two, four, five, six, seven and eight, questions were only collected once. Questions were asked on more than one occasion for lesson one and three since these lessons had more than one instructional strategy and question data was collected from students after each of these. Table 17 illustrates how the question data was collected relative to the lesson number and lesson type, non-contextual or contextual.

Table 17: Collection of Question Data Relative to Lesson Number and Type of Lesson

Question	Lesson	Lesson Type
1	1	Non-contextual
2	1	Non-contextual
3	2	Non-contextual
4	3	Contextual
5	3	Contextual
6	3	Contextual
7	4	Contextual
8	5	Contextual
9	6	Contextual
10	7	Contextual
11	8	Contextual

Students were asked to provide a response to the following: In the space below, write down as many question as you have related to the instructional activity. These questions were analyzed using a question ranking framework, (Klassen et al., 2011 in press) where questions were classified into four types of categories, peripheral, factual, conceptual and philosophical and these four question categories were further subdivided into two levels, level one and level two. This framework was modified to accommodate the work-energy and electromagnetism lessons that students provided questions to and then each question was assigned a numeric value from zero to five based upon the "scoring values assigned to framework categories" from (Klassen et al., 2011 in press), see Table 1. The researcher initially assigned ranking to the questions and then met with Dr. Metz, a co-author of the article, on three subsequent occasions to ensure that the question ranking was being assigned accurately.

Question Ranking Framework

1. Peripheral Questions At the lowest level, there were some questions from which it was impossible to decipher a meaning or that were wholly unrelated to either the instructional context or concepts. They might arise from prior occurrences or off-topic student conversations. The identification of such questions is unproblematic. At a slightly higher sub-level, yet unrelated to the concepts being considered were questions that related to the instructional context

a. Level 1 (P1)

i. Nonsensical: Impossible to decipher a meaning

ii. Irrelevant: Unrelated to learning outcomes or context

Example:

Why are we doing this?

b. Level 2 (P2)

i. Related to learning context

Example:

Are we going to learn more about energy or will we just do more activities?

How does this help us learn about work?

How is drawing musical instruments going to help us make a guitar pickup?

How does this help with the understanding of electric guitar pickups?

2. Factual Questions Factual questions indicate engagement with the instructional concepts at the simplest level.

a. Level 1 (F1)

i. Quantitative: seeks a numerical fact

Question prototype:

What is (value)?

ii. Qualitative: seeks basic factual information

Question prototype:

Yes / No question; What is … ?

Example:

Who came up with field lines?

Do all instruments use magnetism?

Do the lines go on forever?

Who was Tesla and Weber?

b. Level 2 (F2)

i. Procedural: describing a process or dealing with the construction process

Question prototype:

How (to) … ?

Example:

Why did we have to tape before stringing the wire?

Why a bottle for the bridge?

ii. Definition

Question prototype:

What is (definition) … ?

Example:

What is the difference between magnetic flux and induced EMF?

What does the ammeter's direction depend on?

iii. Simple reasoning

Question prototype:

Would (such and such) happen … ?

3. Conceptual Questions Conceptual questions relate to scientific explanation, clarification, hypothesizing, and testing. Concept clarification questions are explanation and clarification type questions. At a slightly higher level, concept elaboration questions have the potential to lead to further inquiry. The further inquiry, prediction, or factor to be investigated should be named or implied in the question.

a. ***Level 1 (C1)***

i. Clarification or elaboration

Question prototypes:

How (does it work) … ?

How do we know that (questioning explanation) … ?

Why (is it that way) … ?

Examples:

How does the length of the string affect the pitch and volume?

Why do we have to put the magnets underneath the screws?

ii. Speculative

Question prototypes:

What would happen if … ?

Is it possible that … ?

Example:

What happens if the screws were spaced further apart?

b. ***Level 2 (C2)***

i. Hypothesis or prediction generating

Question prototype:

What if … ?

Example:

Would the strength/number of magnets change the sound/volume in any way?

Would a stronger magnet mean a louder sound in the guitar pickup?

ii. Hypothesis or prediction testing

Question prototype:

If (condition)… then?

Example:

If the pickup touches the string would the guitar get louder?

If the guitar strings are made of non-magnetizeable metal would nothing happen, simply?

4. Philosophical Questions Philosophical questions indicate the highest level of thinking and, certainly, that critical thinking is at work.

a. Ethical (E1)

Question prototypes:

How should we (act based on evidence, judgment, and values) … ?

Why (do it that way in view of foundational value) … ?

b. Epistemological (E2)

Question prototypes:

How do you know that (questioning foundational presupposition) … ?

5.3.2.2 Comparing the Question Engagement Type Summaries

Students generated 588 questions, 442 questions were collected during the contextual lessons and 146 questions were collected during the non-contextual lessons. Table 18 represents the frequency of questions for the non-contextual lessons and this data is illustrated in Figure 21. The question type generated most frequently was the peripheral level 1 type at 89% and this most frequent question type corresponds to the question with the least amount of student intellectual engagement. The next frequently generated question type was also the next least intellectually engaging question type, the peripheral level 2 question, and it had a frequency of only 5.5%. The next most frequently generated questions were the factual level 2 question at 2.1% and the conceptual level 1 question at 2.7%. For the non-contextual lessons students tended not to generate very complicated questions and the questions that required more depth of thought were generated very infrequently. The least frequently generated question for the non-contextual lessons was the factual level 1 type at 0.7% and as in the case of the contextual lessons the non-contextual lessons generated no philosophical question types.

Table 18: Question Type Non-contextual Summary

Q 1, 2, 3 Sums	146 Questions			
frequency	**Peripheral**	**Factual**	**Conceptual**	**Philosophical**
Level 1	130	1	4	0
Level 2	8	3	0	0

Q 1, 2, 3 Percent	Peripheral	Factual	Conceptual	Philosophical
Level 1	89.0	0.7	2.7	0.0
Level 2	5.5	2.1	0.0	0.0

Figure 21: Non-contextual Lessons Question-Type Percent Summary

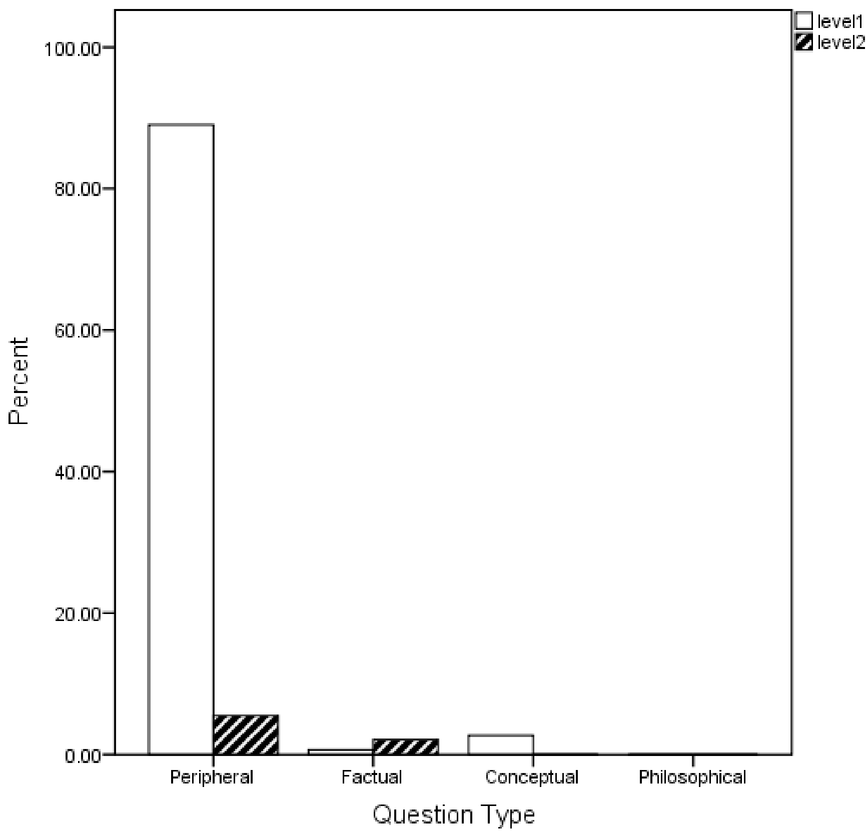


Table 19 contains the question type frequency for the contextual lessons for the four types of questions categories, peripheral, factual, conceptual and philosophical and for the two levels of questions, level one and level two. The top part of the graph contains the frequency of the eight possible question types and the bottom of the graph contains the percent frequency for the question type based upon a total of 442 collected student questions. Figure 22 illustrates the percent frequency for each of the eight possible types a question ranking could be assigned.

For the contextual lessons the type of question that was generated most frequently was the conceptual level 1 category with 42.1% and the next most frequently generated question was the factual level 2 questions with a frequency of 22.4%. The peripheral level 1 and level 2 type questions had a frequency of 15.4% and 14.4% respectively. The question types with the lowest frequency were the factual level 1 type at 9.5% and the conceptual level 2 questions at 5.9%. Students did not generate any philosophical questions.

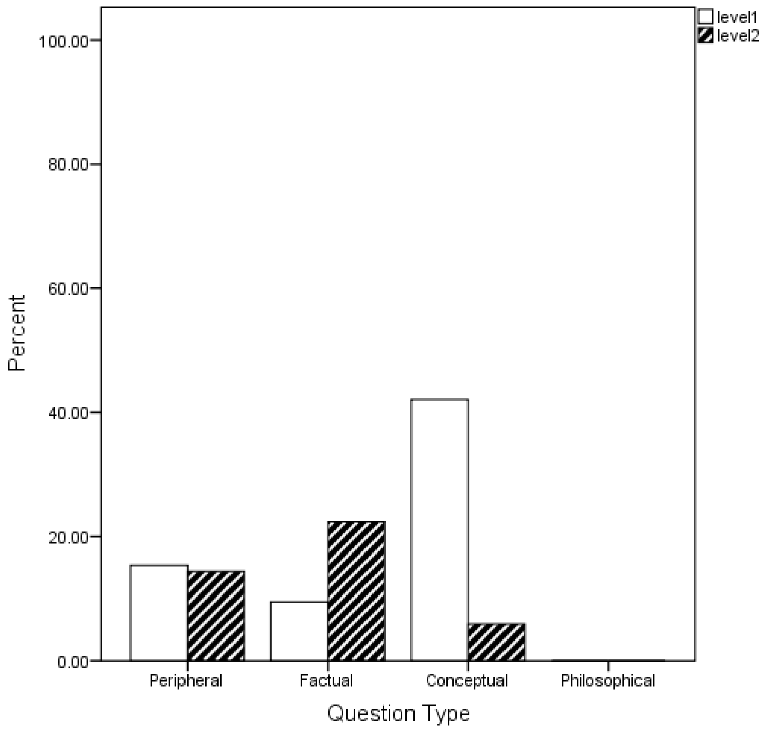
The contextual lessons produced student generated questions after instructional activities that required a high degree of depth of thought and intellectual sophistication. The distribution of question types indicates that students were very highly intellectually engaged for the contextual lessons.

Table 19: Question Type Contextual Summary

Q 4-11 Sums	**442 Questions**			
Frequency	**Peripheral**	**Factual**	**Conceptual**	**Philosophical**
Level 1	68	42	186	0
Level 2	21	99	26	0

Q 4-11 Percent	**Peripheral**	**Factual**	**Conceptual**	**Philosophical**
Level 1	15.4	9.5	42.1	0.0
Level 2	14.4	22.4	5.9	0.0

Figure 22: Contextual Lessons Question-Type Percent Summary



Students were most engaged during the contextual lessons since 42.1% of the questions generated were of the higher order conceptual level 1 type. During the non-contextual lessons the predominantly generated questions were the peripheral type at 89% which required little depth of thought and which clearly indicates that students were not as engaged for these non-contextual lessons. When students generated questions after instructional strategies they were providing a measure of their intellectual engagement. The activities of building the guitar and pickup stimulated the students and their intellectual engagement was higher compared to the non-contextual lessons where no activities were used as instructional strategies.

5.3.2.3 Comparing the Question Engagement Total Student Sums for Each Student

The data in Table 20 represents the student question engagement data including the rank and the gender of the students. Each student answered the following question eleven times during the course of the research, In the space below, write down as many question as you have related to the instructional activity. Each student could provide more than one question and each question was ranked based upon the question framework on a scale of 0 to 4. If more than one question was provided the sum of the question rank became the student's engagement score. The higher the question score meant that the student was more engaged. Students

Table 21 represents each student's engagement total score sum and average for the non-contextual and contextual lessons. Since the non-contextual lessons had three questions contributing to the total engagement sum, this number was divided by three for every student to get an average for each student. The contextual lessons had eight questions contributing to the total engagement sum so these values were divided by eight to get and average for each student. The summary of the engagement sum average for each student can be found in Table 22 and the contextual averages are significantly greater than the non-contextual averages. Figure 23 illustrates that the average engagement sum for each student is significantly greater for the contextual lessons than for the non-contextual lessons.

Table 20: Student Question Engagement Scores for Each of the Eleven Times Question Data was Collected

			non-contextual			contextual							
student	**gender**	**rank**	**q1**	**q2**	**q3**	**q4**	**q5**	**q6**	**q7**	**q8**	**q9**	**q10**	**q11**
1	F	3	2	0	0	0	4	0	6	5	3	2	4
2	F	3	0	0	0	4	0	0	0	2	0	0	0
3	M	1	0	0	2	4	4	2	7	6	9	6	2
4	M	1	0	0	0	0	6	1	9	7	8	8	9
5	F	1	2	0	5	0	3	3	0	5	0	3	5
6	F	1	0	0	0	0	2	0	0	2	0	5	6
7	F	1	0	0	3	3	6	3	8	0	5	7	5
8	M	2	0	0	0	1	2	0	2	2	2	0	3
9	M	2	0	0	0	0	3	0	2	0	4	0	0
10	M	3	0	0	0	2	4	2	12	3	4	1	4
11	M	1	0	0	0	6	6	3	13	0	3	6	10
12	M	1	0	0	0	3	0	0	0	0	8	3	0
13	M	2	0	0	0	0	0	0	12	9	3	9	12
14	M	3	0	0	0	0	0	0	0	0	0	2	0
15	M	1	0	0	0	0	0	6	2	6	3	7	5
16	F	2	0	2	0	2	2	6	1	2	2	0	0
17	F	1	0	0	0	4	2	6	3	3	3	2	2
18	M	1	0	0	0	4	6	26	7	7	6	10	10
19	F	1	0	0	0	0	0	3	3	3	2	3	3
20	M	2	0	0	0	0	5	3	2	3	2	2	3
21	F	1	4	0	2	4	3	15	7	9	10	10	11
22	F	1	0	0	0	0	3	0	0	7	0	0	0
23	F	3	0	0	0	0	0	15	8	13	9	7	6
24	F	3	2	0	0	2	2	9	3	8	1	3	0
25	F	2	0	0	5	0	2	3	2	1	0	0	0
26	M	1	0	0	0	0	0	6	1	7	3	3	3
27	M	3	0	0	0	0	0	0	0	0	0	0	0
28	F	1	0	0	0	3	6	9	6	7	15	7	19
29	F	2	0	0	0	2	2	0	0	2	4	2	3
30	F	1	0	0	0	8	4	9	4	7	2	2	0
31	F	3	5	0	0	3	5	3	4	8	5	5	7
32	F	3	3	0	0	7	7	8	6	11	0	4	6

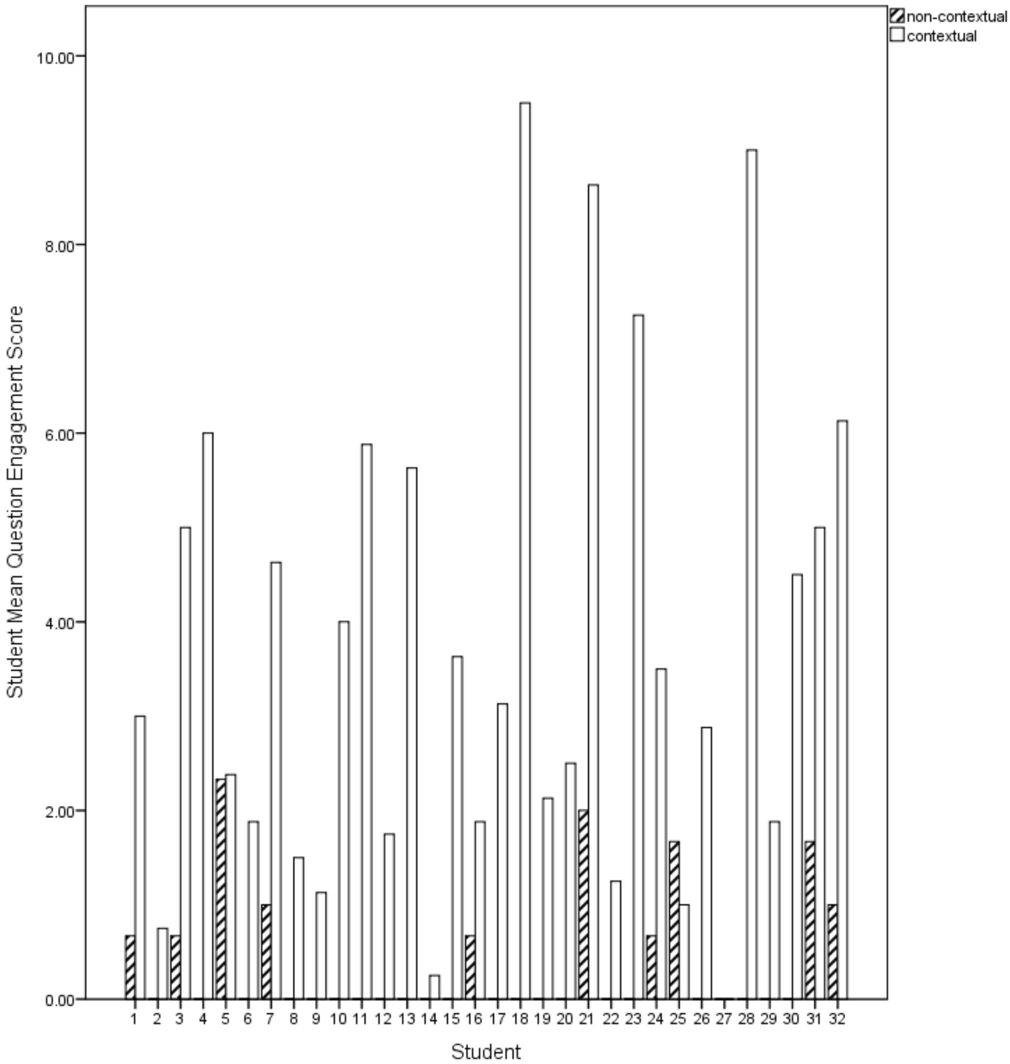
Table 21: Student Question Engagement Sum and Average

	non-contextual					contextual									
subject	q1	q2	q3	sum	average	q4	q5	q6	q7	q8	q9	q10	q11	sum	average
1	2	0	0	2	0.7	0	4	0	6	5	3	2	4	24	3.0
2	0	0	0	0	0.0	4	0	0	0	2	0	0	0	6	0.8
3	0	0	2	2	0.7	4	4	2	7	6	9	6	2	40	5.0
4	0	0	0	0	0.0	0	6	1	9	7	8	8	9	48	6.0
5	2	0	5	7	2.3	0	3	3	0	5	0	3	5	19	2.4
6	0	0	0	0	0.0	0	2	0	0	2	0	5	6	15	1.9
7	0	0	3	3	1.0	3	6	3	8	0	5	7	5	37	4.6
8	0	0	0	0	0.0	1	2	0	2	2	2	0	3	12	1.5
9	0	0	0	0	0.0	0	3	0	2	0	4	0	0	9	1.1
10	0	0	0	0	0.0	2	4	2	12	3	4	1	4	32	4.0
11	0	0	0	0	0.0	6	6	3	13	0	3	6	10	47	5.9
12	0	0	0	0	0.0	3	0	0	0	0	8	3	0	14	1.8
13	0	0	0	0	0.0	0	0	0	12	9	3	9	12	45	5.6
14	0	0	0	0	0.0	0	0	0	0	0	0	2	0	2	0.3
15	0	0	0	0	0.0	0	0	6	2	6	3	7	5	29	3.6
16	0	2	0	2	0.7	2	2	6	1	2	2	0	0	15	1.9
17	0	0	0	0	0.0	4	2	6	3	3	3	2	2	25	3.1
18	0	0	0	0	0.0	4	6	26	7	7	6	10	10	76	9.5
19	0	0	0	0	0.0	0	0	3	3	3	2	3	3	17	2.1
20	0	0	0	0	0.0	0	5	3	2	3	2	2	3	20	2.5
21	4	0	2	6	2.0	4	3	15	7	9	10	10	11	69	8.6
22	0	0	0	0	0.0	0	3	0	0	7	0	0	0	10	1.3
23	0	0	0	0	0.0	0	0	15	8	13	9	7	6	58	7.3
24	2	0	0	2	0.7	2	2	9	3	8	1	3	0	28	3.5
25	0	0	5	5	1.7	0	2	3	2	1	0	0	0	8	1.0
26	0	0	0	0	0.0	0	0	6	1	7	3	3	3	23	2.9
27	0	0	0	0	0.0	0	0	0	0	0	0	0	0	0	0.0
28	0	0	0	0	0.0	3	6	9	6	7	15	7	19	72	9.0
29	0	0	0	0	0.0	2	2	0	0	2	4	2	3	15	1.9
30	0	0	0	0	0.0	8	4	9	4	7	2	2	0	36	4.5
31	5	0	0	5	1.7	3	5	3	4	8	5	5	7	40	5.0
32	3	0	0	3	1.0	7	7	8	6	11	0	4	6	49	6.1

Table 22: Average Question Engagement Score Total Sums

subject	non-contextual	contextual
1	0.7	3.0
2	0.0	0.8
3	0.7	5.0
4	0.0	6.0
5	2.3	2.4
6	0.0	1.9
7	1.0	4.6
8	0.0	1.5
9	0.0	1.1
10	0.0	4.0
11	0.0	5.9
12	0.0	1.8
13	0.0	5.6
14	0.0	0.3
15	0.0	3.6
16	0.7	1.9
17	0.0	3.1
18	0.0	9.5
19	0.0	2.1
20	0.0	2.5
21	2.0	8.6
22	0.0	1.3
23	0.0	7.3
24	0.7	3.5
25	1.7	1.0
26	0.0	2.9
27	0.0	0.0
28	0.0	9.0
29	0.0	1.9
30	0.0	4.5
31	1.7	5.0
32	1.0	6.1
mean	0.4	3.7

Figure 23: Student Average Questions Engagement Score



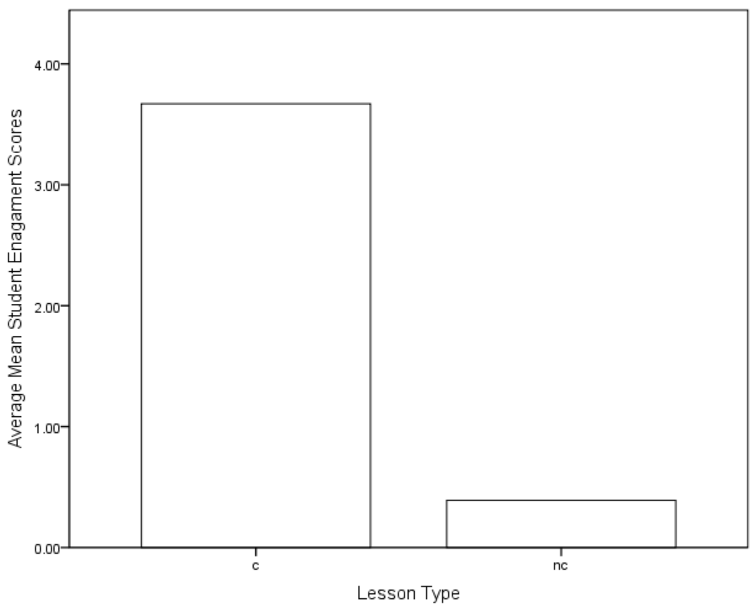
The engagement score sums from Table 22 for the contextual and non-contextual lessons were averaged giving a class average for each instructional type. Table 23 represents the mean non-contextual engagement score sum and a mean contextual engagement score sum for all thirty two students. For the non-contextual lessons the mean and standard deviation was ($\bar{x}$ = 0.4, S_d = 0.7, n = 32) and for the contextual lessons the mean and standard deviation was ($\bar{x}$ = 3.7, S_d = 2.6, n = 32), where $\bar{x}$ = mean and S_d = standard deviation, n = sample size. There is a substantial difference in the average means indicating that students were much more engaged during the contextual lessons than during the non-contextual lessons. Students asked questions related to the instructional activities that were more complex and demonstrated a more complex depth of thought significantly more during the contextual lessons than during the non-contextual lessons. Figure 24 represents the average mean student engagement score and the contextual mean score is substantially greater than the non-contextual average mean.

Table 23: Mean and Standard Deviation for the Question Engagement Scores

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
nc	32	.00	2.33	.3859	.67288
c	32	.00	9.50	3.6741	2.56033
Valid N (listwise)	32				

Figure 24: Student Mean Questions Engagement Score for Non-contextual and Contextual. Lessons



5.3.2.4 Comparing the Question Engagement Total Sums for the Eleven Times Question Data was Collected

Question data was collected eleven times from students and a total sum was now calculated for each of these eleven separate times. Since there were 32 students in the class each of the question sums was divided by 32 to obtain an average score for each of the eleven times question data was obtained by students. In addition, an average engagement score was obtained for the non-contextual and contextual lessons by taking the mean of the non-contextual averages and dividing by three and then taking the contextual averages and dividing by eight. Table 24 illustrates the sum "sum" for each of the eleven times question data was collected, the average "Average sum" for each of these sums and the mean "Mean nc or c" for each of these averages for the non-contextual and contextual lessons. Table 25 represents the summary of the Table 24 data for each time question data was collected. For the three times question data was collected for the non-contextual lessons the student engagement average was only 0.6, 0.1 & 0.5. In contrast, the contextual lessons produced student engagement averages that were much higher, from a minimum of 1.9 to a maximum of 4.5. Figure 25 illustrates the question engagement averages for each question. The contextual question averages are much greater than the non-contextual engagement averages. The questions collected from questions 4-11 represent the contextual lessons and these averages are greater than for the questions collected from questions 1-3, the non-contextual lessons.

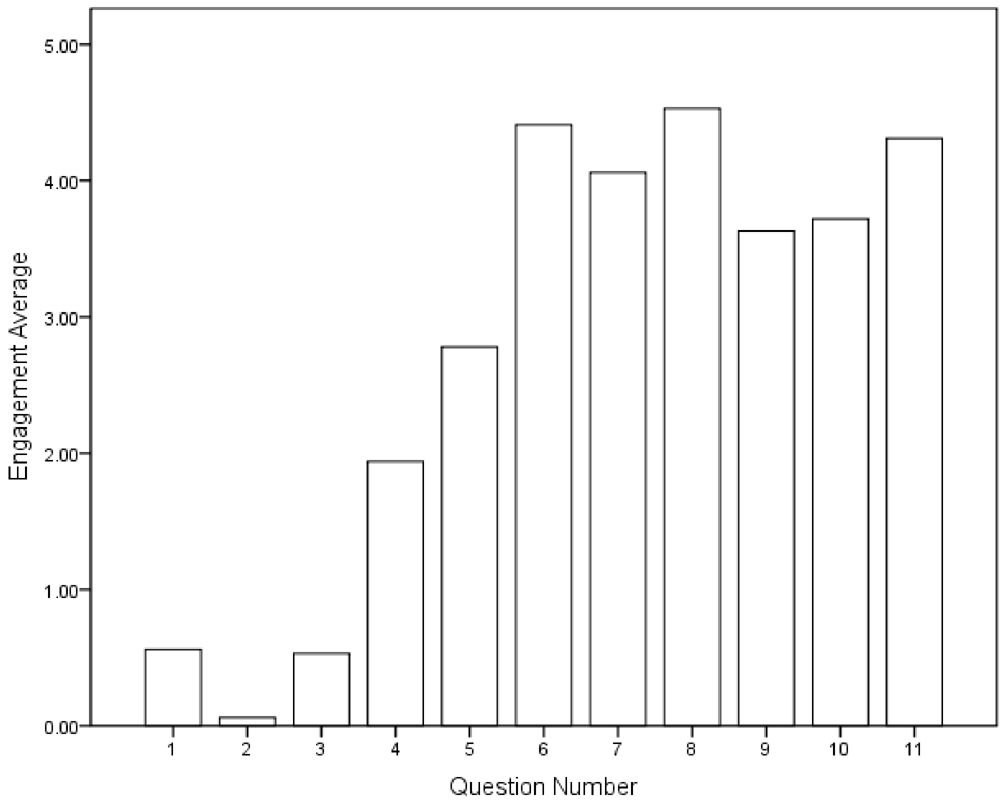
Table 24: The Engagement Average for Each of the Eleven Times Question Data was Collected

	non-contextual			contextual							
student	**q1**	**q2**	**q3**	**q4**	**q5**	**q6**	**q7**	**q8**	**q9**	**q10**	**q11**
1	2	0	0	0	4	0	6	5	3	2	4
2	0	0	0	4	0	0	0	2	0	0	0
3	0	0	2	4	4	2	7	6	9	6	2
4	0	0	0	0	6	1	9	7	8	8	9
5	2	0	5	0	3	3	0	5	0	3	5
6	0	0	0	0	2	0	0	2	0	5	6
7	0	0	3	3	6	3	8	0	5	7	5
8	0	0	0	1	2	0	2	2	2	0	3
9	0	0	0	0	3	0	2	0	4	0	0
10	0	0	0	2	4	2	12	3	4	1	4
11	0	0	0	6	6	3	13	0	3	6	10
12	0	0	0	3	0	0	0	0	8	3	0
13	0	0	0	0	0	0	12	9	3	9	12
14	0	0	0	0	0	0	0	0	0	2	0
15	0	0	0	0	0	6	2	6	3	7	5
16	0	2	0	2	2	6	1	2	2	0	0
17	0	0	0	4	2	6	3	3	3	2	2
18	0	0	0	4	6	26	7	7	6	10	10
19	0	0	0	0	0	3	3	3	2	3	3
20	0	0	0	0	5	3	2	3	2	2	3
21	4	0	2	4	3	15	7	9	10	10	11
22	0	0	0	0	3	0	0	7	0	0	0
23	0	0	0	0	0	15	8	13	9	7	6
24	2	0	0	2	2	9	3	8	1	3	0
25	0	0	5	0	2	3	2	1	0	0	0
26	0	0	0	0	0	6	1	7	3	3	3
27	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	3	6	9	6	7	15	7	19
29	0	0	0	2	2	0	0	2	4	2	3
30	0	0	0	8	4	9	4	7	2	2	0
31	5	0	0	3	5	3	4	8	5	5	7
32	3	0	0	7	7	8	6	11	0	4	6
sum	**18**	**2**	**17**	**62**	**89**	**141**	**130**	**145**	**116**	**119**	**138**
Average question	**0.6**	**.1**	**0.5**	**1.9**	**2.8**	**4.4**	**4.1**	**4.5**	**3.6**	**3.7**	**4.3**
Mean nc or c			**0.4**								**3.7**

Table 25: Question engagement Averages for the Eleven Times Question Data was Collected

question	question engagement averages
1	0.6
2	0.1
3	0.5
4	1.9
5	2.8
6	4.4
7	4.1
8	4.5
9	3.6
10	3.7
11	4.3

Figure 25: Engagement Averages for Each of the Eleven Times Question Data was Collected



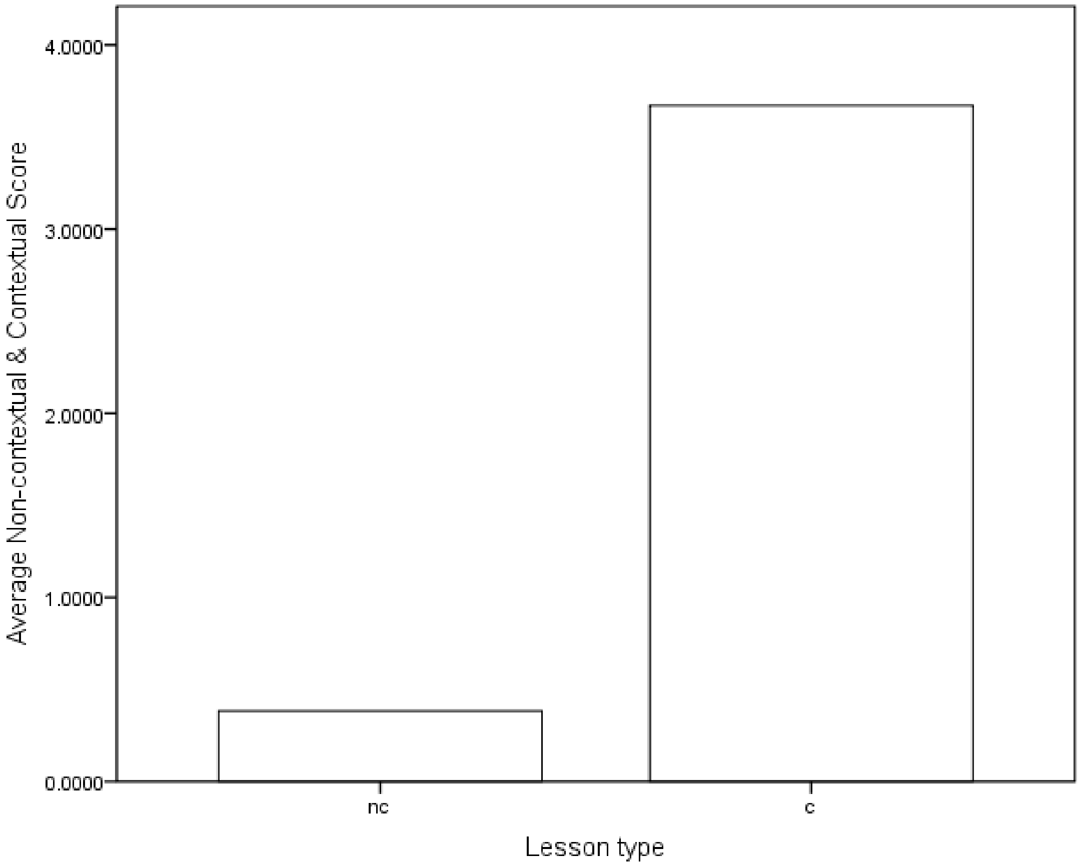
To compare the results for the eleven times question data was collected a mean was taken for the non-contextual averages and a mean was taken for the contextual average. A mean question engagement average was calculated and the non-contextual mean and standard deviation were ($\overline{x}$ = 0.4, S_d = 0.3, n = 3) while the contextual mean and standard deviation were ($\overline{x}$ = 3.7, S_d = 0.9, n = 8), where $\overline{x}$ = mean and S_d = standard deviation, n = sample size, see Table 26. Figure 26 illustrates the mean question engagement average for each time question engagement data was collected for the contextual lessons and the non-contextual lessons and the mean for the contextual lessons is substantially greater..

Table 26: Mean Total Engagement Averages for Non-contextual and Contextual Lessons for the Eleven Times Question data was Collected

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
nclesson1to3	3	.06	.56	.3833	.28042
clesson4to11	8	1.94	4.53	3.6725	.89745
Valid N (listwise)	3				

Figure 26: Mean Non-contextual and Contextual Score for Each of the Eleven Times Question Data was Collected



In the previous section the question data was compared for each student and for this section the question data was compared for the eleven times question data was collected. In each instance the contextual lessons produced results significantly greater for the contextual lessons. When students provided feedback about their engagement through submitting questions and when they provided feedback about their engagement through submitting journals the results were the same. Both the question data and the journal data indicate that students clearly prefer the contextual lessons and are more intellectually engaged during the contextual lessons.

5.3.2.5 Comparing the Question Engagement Score for Different Student Class Rankings

To compare student engagement using ranking, the class was divided into three ranks based on the grade the student had in the physics 40S class at the time of the research. A rank of 1 corresponded to a class grade between 85% & 100%, a rank of 2 corresponded to a class grade between 67% & 84% while a rank of 3 corresponded to a class grade between 50% & 66%. Sixteen students had a ranking of 1 or 50% of the class, seven students had a ranking of 2 or 22% of the class and nine students had a ranking of 3 or 28% of the class. Table 27 represents the average engagement score for each of the three student rankings. The contextual lessons have ranking scores significantly greater than for the non-contextual lessons.

Each group of ranking scores was averaged for both the non-contextual and the contextual lessons resulting in six averages. The six averages represented the three averages for the three non-contextual ranks and the three averages for the three contextual ranks. The mean question engagement score and standard deviation for each rank was calculated and can be found in Table 28. The greatest engagement question score mean was for the rank 1 students ($\bar{x}$ = 4.5, S_d = 2.7, n = 16) during the contextual lessons. The rank 3 students ($\bar{x}$ = 3.3, S_d = 2.6, n = 9) were greater than the rank 2 students ($\bar{x}$ = 2.2, S_d = 1.6, n = 7). This data suggests that a way of increasing the ranking of low performing students may be through the use of contextual teaching methods. For the non-contextual lessons the lowest ranking, rank 3 students ($\bar{x}$ = 0.4, S_d

= 0.6, n = 9) performed about the same as the rank 1 students ($\bar{x}$ = 0.4, S_d = 0.8, n = 16) and outperformed the rank 2 students ($\bar{x}$ = 0.3, S_d = 0.6, n = 7), where $\bar{x}$ = mean and S_d = standard deviation, n = sample size. The standard deviation for the non-contextual ranks have about the same variability and the standard deviation for the contextual ranks have about the same variability. This indicates that the data for the non-contextual ranks and the contextual ranks are clustered closely around their respective means. Figure 27 illustrates the six ranking averages for both the contextual and non-contextual lessons. The contextual ranking scores are significantly greater than the non-contextual ranking scores.

Table 27: Non-contextual and Contextual Engagement Scores by Ranking

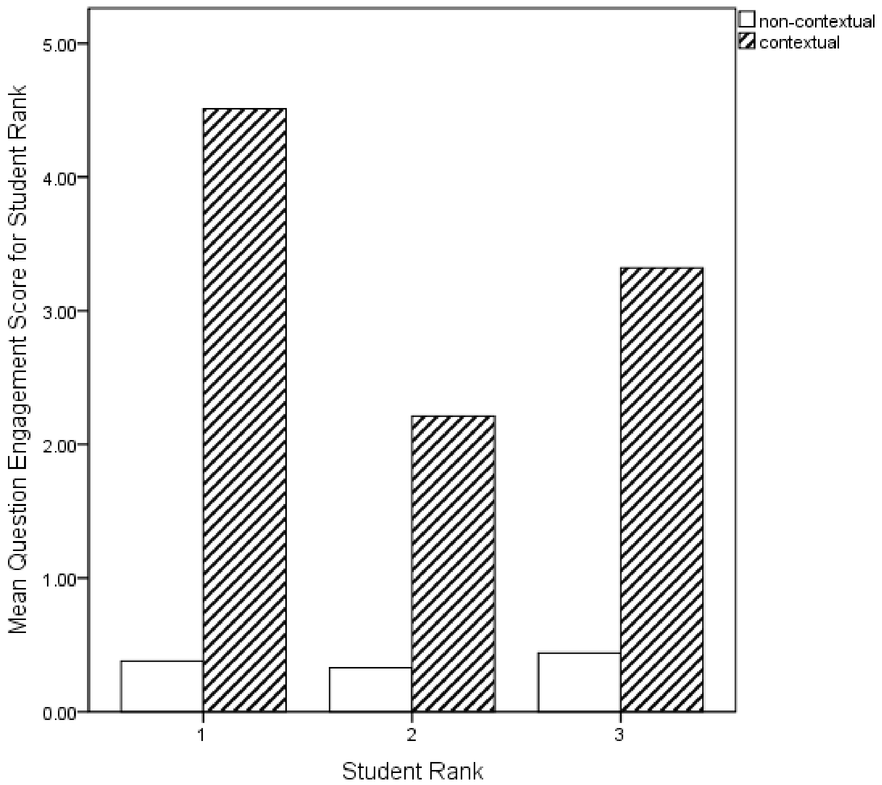
subject	rank	Non-contextual	Mean rank	Contextual	Mean rank
3	1	0.7	0.4	5.0	4.5
4	1	0.0		6.0	
5	1	2.3		2.4	
6	1	0.0		1.9	
7	1	1.0		4.6	
11	1	0.0		5.9	
12	1	0.0		1.8	
15	1	0.0		3.6	
17	1	0.0		3.1	
18	1	0.0		9.5	
19	1	0.0		2.1	
21	1	2.0		8.6	
22	1	0.0		1.3	
26	1	0.0		2.9	
28	1	0.0		9.0	
30	1	0.0		4.5	
8	2	0.0	0.3	1.5	2.2
9	2	0.0		1.1	
13	2	0.0		5.6	
16	2	0.7		1.9	
20	2	0.0		2.5	
25	2	1.7		1.0	
29	2	0.0		1.9	
1	3	0.7	0.4	3.0	3.3
2	3	0.0		0.8	
10	3	0.0		4.0	
14	3	0.0		0.3	
23	3	0.0		7.3	
24	3	0.7		3.5	
27	3	0.0		0.0	
31	3	1.7		5.0	
32	3	1.0		6.1	

Table 28: Mean Non-Contextual and contextual Engagement Scores by Student Rank

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
rank1nc	16	.00	2.33	.3750	.75841
rank2nc	7	.00	1.67	.3343	.63974
rank3nc	9	.00	1.67	.4456	.60208
rank1c	16	1.25	9.50	4.5106	2.67189
rank2c	7	1.00	5.63	2.2171	1.58811
rank3c	9	.00	7.25	3.3200	2.59357
Valid N (listwise)	7				

Figure 27: Mean Question Engagement Score for Students vs. Class Ranking for Non-contextual Lessons and Contextual Lessons



5.3.2.6 Comparing the Question Engagement Score for Student Gender

Table 29 represents the engagement score for student gender. The physics 40S class had 18 or 56.3% females and 14 or 43.8% males in the class. The mean gender data from Table 29 was summarized in Table 30 which includes the standard deviation and sample size. The females had the greatest score for the contextual lessons ($\overline{x}$ = 3.8, S_d = 2.6, n = 18) outperforming the males ($\overline{x}$ = 3.5, S_d = 2.7, n= 14). The females also outperformed the males in the non-contextual lessons, females ($\overline{x}$ = 0.6, S_d = 0.8, n = 18) and males ($\overline{x}$ = 0.1, S_d = 0.2, n = 14), where $\overline{x}$ = mean and S_d = standard deviation, n = sample size. The standard deviation for the non-contextual gender data has about the same variability and the standard deviation for the contextual gender data has about the same variability. This indicates that the data for the non-contextual gender and the contextual gender are clustered closely around their respective means.

Figure 28 illustrates the mean gender data and the graph indicates that for males and females the contextual lessons had greater question engagement scores for the contextual lessons as compared to the non-contextual lessons. Females achieved greater engagement scores for the questions than did the males for both the non-contextual and contextual lessons. The females had higher scores for the question data as compared to the journal data where the females had lower scores than the males. Females reported a higher intellectual engagement when they were asked to provide question data as compared to when they were asked for their personal reflections about their engagement from journals.

Table 29: Question Gender Engagement Scores

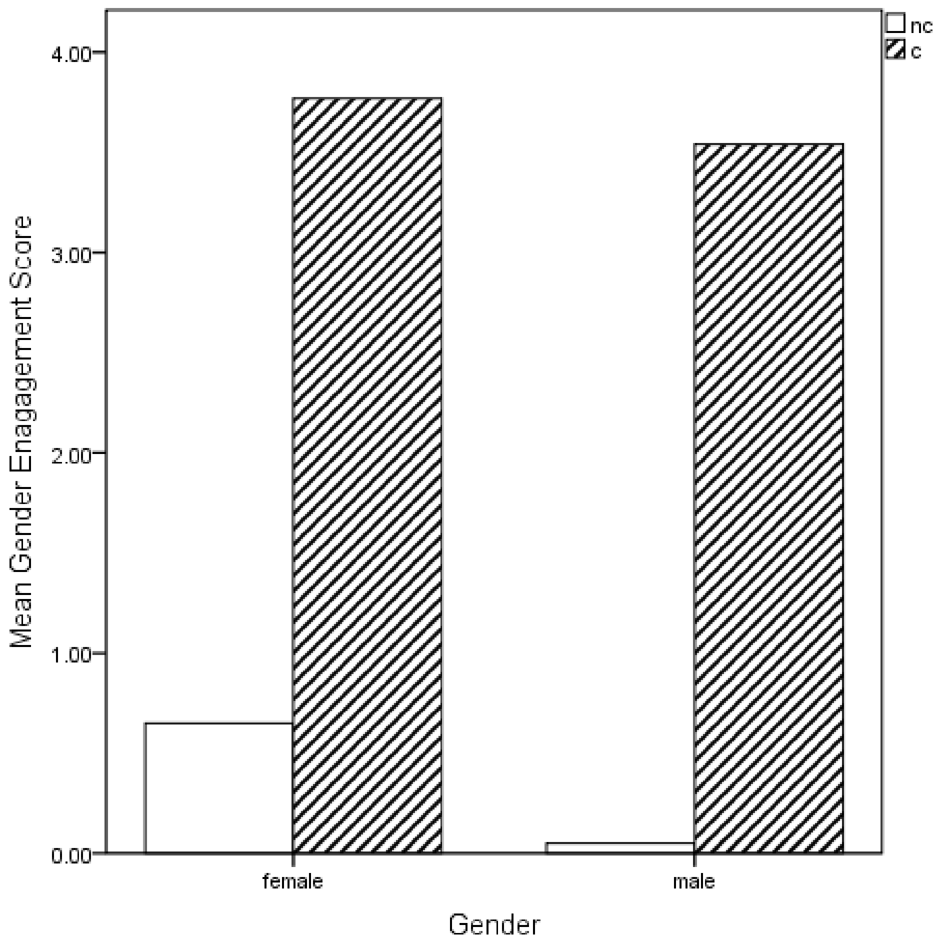
subject	rank	Non-contextual	Mean gender score	Contextual	Mean gender score
1	F	0.7	0.6	3.0	3.8
2	F	0.0		0.8	
5	F	2.3		2.4	
6	F	0.0		1.9	
7	F	1.0		4.6	
16	F	0.7		1.9	
17	F	0.0		3.1	
19	F	0.0		2.1	
21	F	2.0		8.6	
22	F	0.0		1.3	
23	F	0.0		7.3	
24	F	0.7		3.5	
25	F	1.7		1.0	
28	F	0.0		9.0	
29	F	0.0		1.9	
30	F	0.0		4.5	
31	F	1.7		5.0	
32	F	1.0		6.1	
3	M	0.7	0.1	5.0	3.5
4	M	0.0		6.0	
8	M	0.0		1.5	
9	M	0.0		1.1	
10	M	0.0		4.0	
11	M	0.0		5.9	
12	M	0.0		1.8	
13	M	0.0		5.6	
14	M	0.0		0.3	
15	M	0.0		3.6	
18	M	0.0		9.5	
20	M	0.0		2.5	
26	M	0.0		2.9	
27	M	0.0		0.0	

Table 30: Mean Question Gender Engagement Scores

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
femalenc	18	.00	2.33	.6489	.79611
malenc	14	.00	.67	.0579	.17907
femalec	18	.75	9.00	3.7733	2.55521
malec	14	.00	9.50	3.5464	2.65756
Valid N (listwise)	14				

Figure 28: Mean Questions Engagement Score for Students (non-contextual and contextual) vs. Student Gender



5.3.2.7 Comparing the Mean Rotational Graffiti Engagement Scores

The rotational graffiti activity occurred two times during the course of the eight lessons. It served as the opening activity for the non-contextual lesson one and for the contextual lesson three. After each rotational graffiti activity ended, students were asked to provide a response to the following: In the space below, write down as many question as you have related to the instructional activity. Table 31 represents the total engagement score sum for each student's rotational graffiti questions. The student questions were analyzed using the same questions framework as described earlier. The data for the non-contextual engagement sums have many more peripheral scores indicating that students were not very engaged for this activity.

For the non-contextual lesson 1 rotational graffiti students wrote and drew based upon the following three prompts:

1) Write what you know about energy.

2) Write what you know about force.

3) Draw things you push or pull.

For the contextual lesson 3 rotational graffiti students wrote and drew based upon the following seven prompts:

1) Write-What role does music play in your life?

2) Draw-What role does music play in your life?

3) Write-How do musical instruments work?

4) Draw-How do musical instruments work?

5) Write- Where do you find electricity and magnetism in your daily life?

6) Write-Explain about electricity and magnetism?

7) Draw-Explain about electricity and magnetism?

Table 31: Rotational Graffiti Total Question Engagement Scores

Student	Contextual Rotational Graffiti Question Lesson 3 Total Score	Non-Contextual Rotational Graffiti Question Lesson 1 Total Score
1	0	2
2	4	0
3	4	0
4	0	0
5	0	2
6	0	0
7	3	0
8	1	0
9	0	0
10	2	0
11	6	0
12	3	0
13	0	0
14	0	0
15	0	0
16	2	0
17	4	0
18	4	0
19	0	0
20	0	0
21	4	4
22	0	0
23	0	0
24	2	2
25	0	0
26	0	0
27	0	0
28	3	0
29	2	0
30	8	0
31	3	5
32	7	3

No contextual teaching activities had been initiated when the rotational graffiti activity was given at the start of lesson three. No comparison between the lesson three contextual teaching strategy and the lesson one non-contextual teaching strategies could therefore be made. The comparison that could be made was between which context students preferred, work and energy or music. Students seemed to prefer the rotational graffiti activity about music over the rotational graffiti activity about work and energy since their question engagement scores were greater for the music rotational graffiti. Students were more engaged with the context about music since it related to their own lives. Many students play musical instruments and many students enjoy listening to music.

Figure 29 illustrates the total engagement question scores for the thirty two students. A majority of the students had a greater engagement score for the contextual rotational graffiti lesson than for the non-contextual rotational graffiti lesson. To compare the contextual and non-contextual sums the mean and standard deviation for the rotational graffiti engagement score data was determined. Table 32 represents the data where the contextual mean and standard deviation was ($\overline{x}$ = 1.9, S_d = 2.3, n = 32) while the non-contextual mean and standard deviation was ($\overline{x}$ = 0.6, S_d = 1.3, n = 32), where $\overline{x}$ = mean and S_d = standard deviation, n = sample size. Since the mean for the lesson three contextual engagement score was greater than the lesson 1 non-contextual engagement score the students were more intellectually engaged for the contextual activity. Figure 30 illustrates the average lesson three and the average lesson one rotational graffiti mean engagement score. The contextual average is significantly greater than the non-contextual average indicating that students were more intellectually engaged during the contextual activity.

The graphical representation of the two means clearly indicates that the mean student engagement on the contextual rotational graffiti activity was greater than the non-contextual rotational graffiti activity, see Figure 30.

Figure 29: Rotational Graffiti Total Question Engagement Score for Non-contextual and Contextual Lessons

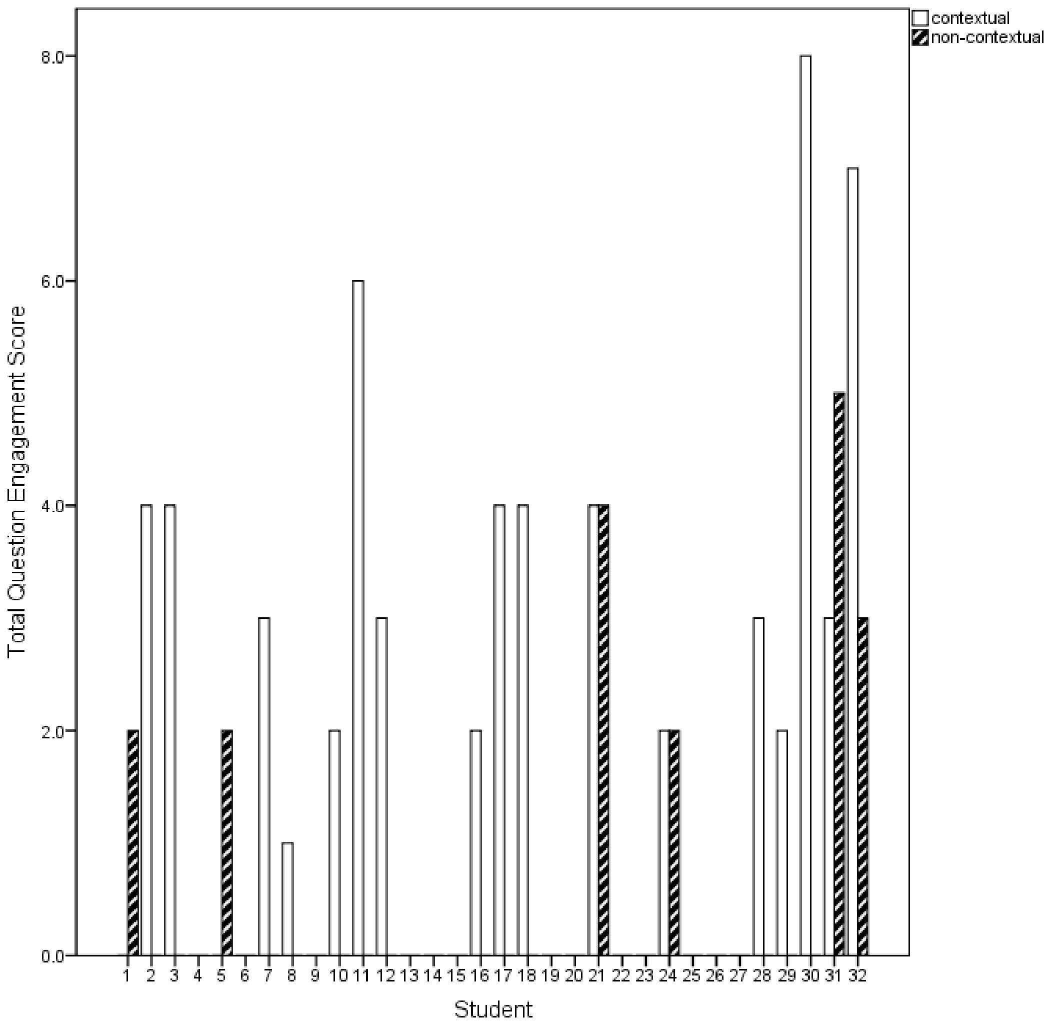
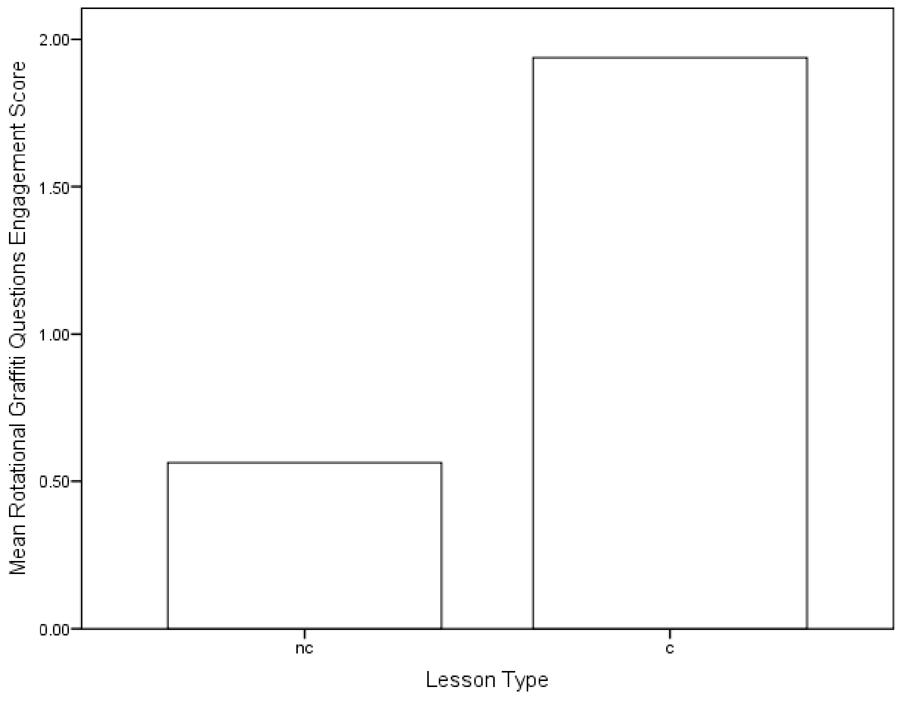


Table 32: Mean Rotational Graffiti Question Engagement Scores

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
contextualrotgrafqscore	32	.0	8.0	1.937	2.2851
noncontextualrotgrafqscore	32	.0	5.0	.563	1.2936
Valid N (listwise)	32				

Figure 30: Mean Rotational Graffiti Questions Engagement Score for Non-contextual Lessons One and Contextual Lessons Three



For this part of the study 32 students were exposed to a rotational graffiti activity at the start of a non-contextual teaching lesson and at the start of a contextual teaching lesson. Students were then given an opportunity to write questions they had during the activity which depending on their depth of thought of the questions, served to provide a measure of student engagement. A paired samples t-test was used to determine if there is a statistically significant difference in the means for the non-contextual engagement scores and the contextual engagement scores. The null hypothesis is Ho: $\mu_d = 0$ and the alternative hypothesis is H_1: $\mu_d \neq 0$, where $\mu_d = \mu_c - \mu_{nc}$ (c = contextual and nc = non-contextual). By conventional criteria, the difference between the contextual and non-contextual mean engagement scores is considered to be extremely statistically significant, t = 3.3, df = 31, p - value = 0.002 < 0.05, see Table 33.

Table 33: T-test Data for Mean Comparison Between Rotational Graffiti Engagement Scores

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	contextualrotgrafqscore - noncontextualrotgrafqscore	1.3750	2.3521	.4158	.5270	2.2230	3.307	31	.002

5.3.3 Research Question 1 Summary

Research Question 1. How does the engagement of physics students compare when they are taught using a contextual learning strategy as compared to a non-contextual learning strategy?

When comparing the engagement between the non-contextual lessons and the contextual lessons it is clear from all the data collected that the contextual lessons provided the greatest engagement. Two summary tables are provided listing all the results for the journal and question data. Table 34 summarizes the journal data and Table 35 summarizes the questions data. The summary data tables contain final numerical results for the different analysis including the mean, standard deviation and sample size n. The tables also includes the relevant thesis section where the data was analyzed.

Table 34: Summary of Student Journal Data

	non-contextual(nc)			contextual(c)			thesis section
	mean score 0-4	s.d	n	mean score 0-4	s.d	n	
students	**0.7**	0.8	26	**2.2**	0.9	26	5.3.1.2
lessons	**0.7**	0.4	2	**2.3**	0.4	6	5.3.1.3
rank 1	**0.3**	0.4	12	**2.4**	0.2	16	5.3.1.4
rank 2	**1.5**	0.5	5	**2.4**	0.6	7	
rank 3	**0.8**	0.9	9	**1.7**	0.8	9	
male	**1.1**	0.9	11	**2.6**	0.5	14	5.3.1.5
female	**0.4**	0.5	15	**1.9**	1.0	18	

Table 35: Summary of Student Question Data

	non-contextual(nc)			contextual(c)			thesis section
	mean sum	s.d	n	mean sum	s.d	n	
students	**0.4**	0.7	32	**3.7**	2.6	32	5.3.2.3
questions	**0.4**	0.3	3	**3.7**	0.9	8	5.3.2.4
rank 1	**0.4**	0.8	16	**4.5**	2.7	16	5.3.2.5
rank 2	**0.3**	0.6	7	**2.2**	1.6	7	
rank 3	**0.4**	0.6	9	**3.3**	2.6	9	
male	**0.1**	0.2	14	**3.5**	2.7	14	5.3.2.6
female	**0.6**	0.8	18	**3.8**	2.6	18	
rot.graffiti	**0.6**	1.3	32	**1.9**	2.3	32	5.3.2.7

For the journal engagement data scored from 0 to 4, the mean student contextual score of 2.2 was much greater than the non-contextual score of 0.7, Table 7. A t-test was done on the means of the student journal data and it was determined that the difference in the means was statistically significant with $t = 7.7$, $df = 25$ and $p\text{-value} < 0.001$, Table 8. To ensure that the data was not skewed the mean journal engagement data was compared for each of the 8 lessons. This was done so that the difference in the contextual and non-contextual scores was not just a result of the activity but was a result of the context of the activity. The mean journal score of 2.3 for the contextual lessons 3-8 was much greater than the mean journal score of 0.7 for the non-contextual lessons 1&2, Table 12. The two lowest contextual lesson scores of 1.7 and 1.9 from lessons 4&5 were still significantly larger than the two non-contextual lesson scores of 1.0 and 0.5 from lessons 1&2, Table 11.

The analysis of the journal ranking data revealed that for all three student rankings the contextual lesson engagement scores were greater than the non-contextual engagement scores, Table 14. The journal gender data revealed that both males and females had higher engagement scores for the contextual lessons compared to the non-contextual lessons. Male students outperformed the female students in both the contextual and non-contextual lessons but the female contextual scores were close to the male scores, Table 16.

After analyzing the questions based on the questions framework it was determined that the level 1 non-contextual peripheral category had the highest percent frequency of 89%, Table 18. The highest question framework category for the contextual lessons was for the level 1 conceptual category with a percent frequency of 42.1 %, Table 19. For the contextual lessons the question categories that required a greater depth of thought such as the factual and conceptual categories had percent frequencies far greater than the non-contextual lessons.

After analyzing the mean sums for the student question engagement data it was determined that the contextual engagement mean sum of 3.7 was much greater than the non-contextual mean sum of 0.4, Table 23. To ensure this data was not skewed the mean student question engagement data was compared for each of the eleven times question data was taken. Question 1-3 data was obtained during the non-contextual lessons and question 4-11 data was obtained during the contextual lessons. This was done so that the difference in the contextual and non-contextual question engagement sums was not just a result of the activity but was a result of the context of the activity. The mean question engagement sum of 3.7 for the contextual questions 4-11 was much greater than the mean question engagement sum of 0.4 for the non-contextual questions 1-3, Table 26. The three lowest contextual question averages of 1.9, 2.8 and 3.6 from questions 4,5&9 were still significantly larger than the three non-contextual sums of 0.6, 0.1 & 0.5 from questions 1-3, Table 25.

When comparing the contextual and non-contextual student ranking data it was determined that the contextual engagement scores were greater than the non-contextual engagement scores for all student ranking. The rank 1 students had the greatest score with 4.5 followed by the rank 3 students with 3.3 followed by the rank 2 students with 2.2, Table 28. The non-contextual rank 1 and rank 3 students had the greatest score with 0.4 followed by the rank 2 students with a score of 0.3. In terms of gender the females had greater question engagement scores than the males for both the contextual and non-contextual lessons, Table 30. The rotational graffiti data I collected from students indicates that they prefer the contextual lessons to the non-contextual lessons . The mean student engagement score for the contextual rotational graffiti activity was 1.9 while the non-contextual rotational graffiti score was 0.6, Table 32. The difference in the rotational graffiti engagement means was found to be statistically significant since a t-test revealed, $t=3.3$, $df=31$ and $p\text{-value}=0.002<0.05$, Table 33.

5.4 Research Question 2

The second Research Question is: Do physics students prefer the contextual or non-contextual teaching strategy and what attitudes do physics students have about the contextual and non-contextual learning strategies?

To answer this research question the journal data obtained from the following four questions were used:

1) What did you like?

2) What did you not like?

3) Comment on the way the lesson was presented.

4) Comment on how the lesson interested you.

These questions were answered by students at the end of each lesson and students were free to write as much as they liked. The non-contextual lessons were lessons one and two and involved work and energy topics presented from a textbook while the contextual lessons were lessons three to eight and involved electromagnetism presented with hands-on activities.

To determine the student preference for the non-contextual or contextual lessons their journal responses were analyzed for common themes, words, phrases and attitudes.

An attitude is a way or tendency of thinking and to analyze student attitudes, they will be measured using Osgood's semantic differential scale where I will look for student comments that contain bipolar adjectives such as: like, dislike, bored, not-bored, interested, not-interested, confused, not-confused, good, bad, favorable, unfavorable (Osgood et al.,1957).

5.4.1 Non-contextual Student Preferences and Attitudes

In looking at what students liked about the non-contextual lessons a majority of them wrote that they liked how easy the questions were. Some students wrote: " It was easy and fast.", "Easy exercises.", "How easy these questions are.", "I liked how there wasn't much thinking about the questions." Many students also wrote that they liked the practice questions and textbook examples writing: "The practice problems."," I like doing some practice during the class."

When analyzing what students disliked about these lessons it was very evident that they did not like the method of using the textbook as an instructional strategy. One student wrote the following: "The textbook doesn't explain how or why formulas work as they do, so there is no meaning to the equation W=**Fd** and it is difficult to understand [not practice] some of the concepts.", " I did not like the fact that we need to do the questions from the text because it was pretty boring even though it was easy.", "I didn't like how the textbook acts as a dictation opposed to a teaching session.", "What I didn't like was the textbook part."

When students were asked to comment on their interest level for the non-contextual lessons almost half indicated that the lessons were boring. Students wrote, "Boring because only reading the textbook.", "Reading it from textbook was boring and confusing at the same time.", "I hate textbook, working on textbook is boring.", "Overall, this lesson was boring." About the same number of students responded that the lessons were not interesting as responded that the lessons were boring. Some student comments indicating that they found the non-contextual lessons not interesting are as follows: " It was not that interesting because it was from the textbook.", "This lesson didn't really interest me.", "I was just reading from the textbook with some practice questions.", "I paid attention because it was a new concept although it wasn't very interesting or exciting.", "This did not interest me at all.", "The lesson did not interest me. " The final two most frequent student comments but less frequent than the boring and not interesting comments were that the non-contextual lessons were slow moving and confusing. Students wrote:" I found the lesson a little slow moving.", "It was pretty much like a dictation and it was hard to concentrate.", "This lesson was a little more interesting but I still found it slow.", "Was confusing and not interesting at all."

The following student comments for both the non-contextual lessons is a fair representation for the class comments: A representative lesson one comment is as follows:" This lesson was simple but interesting in terms of content and the concepts were easy to understand once Mr. Lukie explained them on the board. Unfortunately, the textbook did not thoroughly explain the topic but rather, rehashed the same concepts over and over, which was boring. Nevertheless, the lessons covered all the basics and it was interesting to learn about work. It was not, however, interesting enough to hold my attention for the entirety of the 2 hour class since the text was quite repetitive and slow moving. Overall, this lesson was boring." A representative lesson 2 comment is as follows: " This lesson too, was quite boring. There was nothing wrong with the topic (which, although relatively simple, was not that boring yet, it was not a topic that required so much time and text to understand. The use of cosθ was not explained well, and the lesson simply repeated the first lesson's concepts. This was not very interesting and there was no use for student involvement or questions so I felt no need to "connect" with the lesson. We didn't even have to take notes."

5.4.2 Contextual Student Preferences and Attitudes

The contextual lessons used a combination of PowerPoint lessons, demonstrations and hands on activities. A majority of the students commented that they really liked the hands on activities because they were allowed to play with physics. Many of the students also wrote that they liked to discover physics for themselves rather than being told facts with the expectation that they should believe what the teacher told them. Students wrote: " I liked the part that I learned that electricity cannot be created by just holding it near copper wires, you have to be moving the magnet to produce electricity. I also like the part because if we would have just read that, it would be harder to believe, but now thanks to the visual experiment I learned more about this topic.", "I liked being able to do a lab and actually seeing the results instead of having the teacher tell you the results."," I liked that it was hands on."," Ability to discover for ourselves without having to believe textbooks.", "I liked that we got to play with the magnets ourselves to really see the magnitude of **B** due to different actions.", "It was better than reading this from a textbook. I got to play with magnets which was interesting."

Many students also liked the lesson demonstrations commenting that the visualization of the lesson concepts helped with their understanding. Comments included: "I liked seeing these demos, they gave me a better understanding.", "The demos helped me to understand the concepts.", "Having the demo to demonstrate the guitar pickup.", "The demonstrations were pretty cool."," I liked watching magnets at work, and the huge Duracell batteries were cool."," I also liked the practical demonstration of the lesson."

The most positive comments came from students after the guitar pickup was built. Students wrote that the building activity was fun and some indicated that it was the highlight of their school year. Students wrote: "I loved everything, this was the highlight of this school year. It showed me how I can use electromagnetism at home.", "Oh my god, this is so amazing, everybody loves the physics of the guitar pick up, this stuff is more fun.", "I enjoyed how hands-on this lesson was. It was fun to build something.", "I loved that I was able to use physics to build something useful.", Many students also wrote that they especially liked how all the electromagnetism concepts they were learning about were brought together in the pickup construction. Students wrote: "I liked how all the topics we've been learning about came together.", "I like how it all makes sense now.", "The hands-on activity of building the guitar related all of the concepts we've been learning about."

Students had far fewer dislikes than likes for the contextual lessons. Many students did comment that they did not like the PowerPoint presentations because they resembled the textbook lessons and some suggested that they would have preferred to have taken notes rather than be given handouts. Some comments were: " I did not like the PowerPoint notes because it was the same method as the learning from a textbook..", "PowerPoint was boring"," I find it easier to learn when I take notes and ask questions, so handouts don't help me that much."," I did not like PowerPoint.". A number of students did not like having to write in the journals and some did not like working in groups.

Some students wrote:" I did not like that we had to work in groups.", A few students wrote that they did not like the formulas since the electromagnetism formulas were too complicated and difficult to understand, " The formulas were too conceptual."," I didn't like the formulas." Finally, a number of students did not like the amount of work that was involved in building the pickup. Some comments were:"Lots of work", "Hard to tune the string", "How long the winding process takes".

When students commented on their interest level about the contextual lessons many students wrote that they were interested in the lessons since the topic related to their own lives, some students were musicians and played guitar while others simply like to listen to music. Students wrote:" I play guitar so learning about it interested me.", "It interested me because I like music, building things and learning things in creative ways. This is the BEST way to learn physics.", "Guitars are something I enjoy and the fact that Φ relates to them was cool."," The lesson was very interesting because I'm a huge music fan, and I can finally understand how music is propelled." , "I love music, so seeing a way to make a guitar better than elastic bands over an empty Kleenex box was really cool. If I had the materials I'd make it myself."

A clear majority of students wrote that they were especially interested in the history of the electric guitar lesson. Some comments are: " Learning about the history of the guitar and how electromagnetic pickups work was very interesting, especially considering the fact that I play guitar as well.", "This lesson was more interesting than the other 2. First, it was presented in an original way (without just reading the textbook and doing practice questions). Second, the topic was unique and I found the history of the guitar to be more interesting."

Students who found the lessons interesting because they were fun wrote the following comments: "I was really interested. I liked the part that we built something and then played with it. It deals with music and I like music a lot. I learned a lot and had fun.", "I was engaged, I learned the physics behind the activity and I was able to apply these ideas. It was a well rounded approach to learning physics that was also loads of fun.", "Very interesting, the guitar building is fun.", "Physics is fun. This is amazing, it interested me a lot."," The lesson was presented in a super creative way since we had fun and learned a lot. I would have not learned as much from a textbook as I did with this activity."

As with the "What did you like" comments a large number of students found it interesting that the construction of the guitar pickup related all the electromagnetism lessons and students found the hands on activities interesting. Students wrote: "This lesson was really interesting to me because I wanted to know how the guitar pickup worked. This lesson related all of the formulas and concepts.", "It is interesting seeing all the physics come together and work.",

Comments related to student interest about the hands on activities and demonstrations were: "I found it interesting because we were able to not only learn new concepts but also try them ourselves.", "The magnetic field was interesting to see work!", "I was really interested in the lesson because I like to see things visually rather than just speaking/reading from a textbook. I got a better understanding of the topic."

5.4.3 Research Question 2 Summary

Research Question 2. Do physics students prefer the contextual or non-contextual teaching strategy and what attitudes do physics students have about the contextual and non-contextual learning strategies?

In summary students did not prefer the non-contextual lessons finding the textbook instruction delivery boring, not interesting, slow moving and confusing.. Although they liked the quick and easy practice questions, students disliked that the textbook did not provide context or meaning for the formulas used. Students preferred the contextual lessons finding them to be very interesting and fun. They liked the hands on activities because of the discovery learning, the demonstrations because students could see the physics rather than just being told about it and they especially liked the pickup building activity. Since the pickup was difficult to construct and required much work some students disliked this aspect of the activity. Interest was high since the contextual lessons related to student interest with music and with playing guitar. The pickup building activity brought all the electromagnetism concepts together and students could see the physics relationships within the pickup. Students disliked learning from the PowerPoint since it was similar to the textbook learning, writing in the journal, group work and the difficulty of the conceptual difficulty with the electromagnetism formulas.

5.5 Research Question 3

The third Research Question is: How does the level of student understanding of work, energy and electromagnetism compare with my previous experience of teaching without using contextual teaching.

In my experience of primarily using a non-contextual teaching approach to teach work, energy and electromagnetism from a textbook for the last 10 years, I have discovered that student understanding of work and energy is greater than their understanding of electromagnetism. Students seem to connect with work and energy more than with electromagnetism since work and energy relates to their daily lives and experience. Electromagnetism offers no real world reference point for which students can relate to and as a result they have difficulty understanding this concept. The number of formulas for work and energy are fewer than for electromagnetism and I have found that students become overwhelmed with the large number of electromagnetism formulas. The conceptual nature of electromagnetism intimidates students and it was my hope that through using a contextual teaching approach, I could increase student understanding. I wanted students to be able to achieve the same level of understanding or better as a result of the contextual teaching strategy. To determine if the level of student understanding remained the same, increased or decreased, I compared the student's current grade in the physics class to their grade obtained from two final unit tests given at the end of the non-contextual textbook lessons and the contextual guitar building lessons.

When selecting questions for the non-contextual unit test I used questions taken directly from the textbook. These questions were very similar to questions I have used previously and reflected the same level of difficulty, (Appendix L). The questions that were used for the electromagnetism unit test involved drawing field lines, calculating flux, Lenz's Law and Faraday's Law of Electromagnetic Induction, (Appendix M). I have previously used all of these types of questions except for the Faraday question where electromotive force was calculated when magnetic field, area or angle changed with respect to time. The final unit test for the electromagnetism lessons had more concepts than I have included in the past and was therefore a more challenging student assessment.

5.5.1 Comparing Current Student Mean Class Grade With Their Mean Grade Obtained During Cumulative Tests From the Non-contextual and Contextual Lessons

Students wrote two cumulative tests during the eight lesson unit. The first test was written after the non-contextual textbook lessons on work and energy and the second test was written after the contextual guitar pickup building lesson. Since I had a current grade for each of the thirty two physics 40S students prior to the research I wanted to compare their current class grade with their grades obtained on the non-contextual and contextual final unit tests. The first test was given after lesson two and consisted of work and energy concepts while the second test was given after lesson eight and consisted of all the electromagnetism concepts. Table 36 represents the student current grade and the final unit test grade scored out of twenty marks and converted to a percent.

Since a before and after comparison was being made for the student grades, only comparisons could be made for students who were present for both the non-contextual and contextual tests. Data could therefore not be used for the following twelve students; 1, 2, 9, 12, 13, 15, 16, 20, 22, 23, 26 and 28. Table 37 represents the resulting corrected data of twenty students with a current physics 40S class grade and a grade for their non-contextual and contextual unit tests.

Table 36: Student Current Class Percent Grade and Percent Grade on Two Cumulative Tests

student	Current class grade %	Non-contextual test grade %	Contextual test grade %
1	54	absent	50
2	52	75	absent
3	98	95	85
4	85	85	100
5	86	95	82.5
6	87	95	85
7	97	95	85
8	74	80	70
9	84	90	absent
10	65	85	57.5
11	86	85	92.5
12	86	80	absent
13	76	absent	70
14	50	75	70
15	98	absent	90
16	76	95	absent
17	92	90	95
18	100	85	85
19	87	85	95
20	76	absent	77.5
21	95	90	100
22	85	95	absent
23	64	absent	90
24	52	80	65
25	81	65	75
26	90	absent	90
27	55	80	55
28	90	absent	95
29	70	45	85
30	94	40	75
31	60	75	70
32	50	70	70

Table 37: Modified Student Test Data Correcting for Student Absence

student	Current class grade %	Non-contextual test grade %	Contextual test grade %
3	98	95	85
4	85	85	100
5	86	95	82.5
6	87	95	85
7	97	95	85
8	74	80	70
10	65	85	57.5
11	86	85	92.5
14	50	75	70
17	92	90	95
18	100	85	85
19	87	85	95
21	95	90	100
24	52	80	65
25	81	65	75
27	55	80	55
29	70	45	85
30	94	40	75
31	60	75	70
32	50	70	70

Table 38 represents the mean and standard deviation for the current class grades, non-contextual test grades and contextual test grades. Each test grade had approximately the same average of 80%.

Table 38: Mean and Standard Deviation for the Current Class Grade, Non-contextual Test Grade and Contextual Test Grade

Descriptive Statistics

	Mean	Std. Deviation	N
Current-grade	78.20	17.289	20
Non-contextual Grade	79.75	15.259	20
Contextual Grade	79.875	13.2654	20

These three test grades are very similar and show little variation indicating that the non-contextual and contextual unit tests had little effect on the standing a student had in the class. There appears to be no change in a student's test grade after the non-contextual and contextual lessons were administered and the students achieved at least the same level of understanding .

5.5.2 Research Question 3 Summary

Research Question 3. How does the level of student understanding of work, energy and electromagnetism compare with my previous experience of teaching without using contextual teaching?

Student performance with work and energy did not change after the non-contextual lessons were taught and this corresponds to my previous teaching experience. I expected that student performance should remain the same after the non-contextual textbook lessons were taught since these lessons where similar to lessons I have taught in the past. The current grade students had prior to the non-contextual textbook unit test remained very similar with their grade after the unit was taught. The mean grade the class had before the non-contextual lessons were taught was approximately 80% and the mean class grade after the non-contextual lessons were taught was approximately 80%. Student test performance after the contextual lessons were taught was approximately 80% and this also showed little difference with their grade prior to the contextual lessons being taught. Although student test performance was the same, at least their performance did not decrease as a result of the contextual lessons. Students achieved the same level of understanding and the contextual electromagnetism lessons did not detrimentally affect a student's current standing in the physics class.

5.6 Research Question 4

The fourth Research Question is: Is it possible to motivate S4 physics students in a meaningful, contextual learning activity that facilitates a deeper understanding of the concepts of electromagnetism?

To examine if students were motivated by the contextual learning activities, data collected from the teacher journal and from the student journals was examined. For students to be motivated I assumed that they must also be engaged and interested in the activities and if they were interested then the activities would facilitate a deeper understanding of their concepts of electromagnetism. To determine if students had a deeper understanding of electromagnetism I looked at the test scores students obtained from two exit slips and from their non-contextual and contextual final unit test scores compared to their current class grade.

5.6.1 Teacher and Student Journals

When reviewing my teacher journal I looked for entries where I commented on how motivated and engaged I thought the students were during the non-contextual and contextual lessons. After the first non-contextual lesson I commented on how bored the students were with the textbook lesson and how uninterested many of the students appeared. The students listened to the lesson but asked very few questions when the lesson ended. I wrote how quiet the students were after the second non-contextual lesson and that the students were not talking to each other or sharing and comparing exercise solutions amongst themselves. I also wrote that I could not determine if the students were engaged or were interested in the textbook lesson because I was getting no feedback from the students. An interesting comment that I wrote in the journal was that I was amazed how little guidance students required for these lessons. Students seemed to know what to expect from the lesson and what was expected of them. I wrote that since many students have been exposed to textbook instructional delivery methods many times in the past they were very familiar with this method of teaching and knew how to behave. I wrote that the two textbook lessons reminded me of Paolo Freire's banking conception of education. In the banking conception of education teachers take control of the lessons and determine what will be learned by passive students who were expected to memorize and regurgitate the facts taught to them. Students accept the world as it is and the students' consciousness is separated from the world contributing to their oppression. (Freire, 1970).

In sharp contrast, my teacher journal entries for the contextual lessons are full of positive comments about how interested and motivated students were. After the first contextual rotational graffiti lesson I wrote that students were much more talkative and were more willing to share ideas than they had previously been for the rotational graffiti about work and energy. Although some of the Power Point presentations were similar to textbook lessons, students were much more engaged with the content and asked me many questions. During the demonstrations I wrote that students were very willing to ask questions about physics and seemed interested to play with the demonstration apparatus. When students were building the guitar pickups I wrote in my teacher journal that they worked well together and openly discussed strategies to most effectively build the pickup. Students also made suggestions to me about how the guitar design could be improved using a block for the bridge rather than a bottle. I also wrote in my journal that students suggested that 6 strings should be incorporated into the design so that the guitar would be more realistic. At the end of contextual lesson six I wrote that the contextual lessons reminded me of Freire's problem-posing conception of education. In the problem-posing conception of education students and teachers carry on a dialogue to teach one another where students are active learners. This conception encourages inquiry and recognizes the relationship between people and the world which leads to transformation. According to Freire, “Knowledge emerges only through invention and re-invention, through the restless, impatient, continuing, hopeful inquiry human beings pursue in the world, with the world, and with each other” (Freire, 1970, p.72).

Students commented in their journals that the non-contextual lessons were boring and uninteresting while the contextual lessons were fun and interesting. A few representative student comments about the contextual lessons are: "The lesson was presented in a super creative way since we had fun and learned a lot. I would have not learned as much from a textbook as I did with this activity." ,"It interested me because I like music, building things and learning things in creative ways. This is the BEST way to learn physics." Some student comments about the non-contextual lessons are: "The lesson did not interest me. ""Overall, this lesson was boring." Some student comments about the contextual lessons indicated that they really connected to the electric guitar pickup context. A student wrote "Oh my god, this is so amazing, everybody loves the physics of the guitar pickup, this stuff is more fun." From the positive comments students wrote about the contextual lessons it is clear that they were motivated and intellectually engaged by the activities.

5.6.2 Exit Slips and Final Unit Tests

Two brief exit slip questions were given to students during the contextual lessons to help determine if the learning activity helped facilitate a deeper understanding of the concepts of electromagnetism and to ensure that students understood the concepts after the lessons had been taught. These brief concept tests involved a short question about magnetic flux from contextual lesson three and a short question about Lenz's law from contextual lesson four, (Appendix J, Appendix K). Each exit slip was scored out of three and was converted to a percent. To calculate the mean score for each lesson the sample size was adjusted for students who were absent. Table 42 represents the mean and standard deviation, the flux exit slip was: ($\overline{x}$ = 96.8, S_d = 10.0 , n = 31), and for the Lenz's law exit slip ($\overline{x}$ = 91.0, S_d = 25.9, n = 26) where $\overline{x}$ = mean and S_d = standard deviation, n = sample size.

Table 39: Exit Slip

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
exitslip1	31	66.70	100.00	96.7774	10.00789
exitslip2	26	.00	100.00	91.0231	25.92494
Valid N (listwise)	25				

These two exit slip questions were similar to questions I have given in the past and I expected that if the students understood the concepts then they would obtain a high grade on these exit slips. Students did very well on these exit slips and it appears that the contextual lessons provided students with a high level of understanding.

When comparing the current grade a student had in the physics class to their non-contextual and contextual final unit tests it was determined that all three tests resulted in the about the same test scores of approximately 80%, see research question three. This indicates that after the contextual lessons were taught, students achieved about the same level of understanding as they had prior to the lessons.

5.6.3 Research Question 4 Summary

Research Question 4. Is it possible to motivate S4 physics students in a meaningful, contextual learning activity that facilitates a deeper understanding of the concepts of electromagnetism?

Students were motivated with the contextual activity since the teacher journal and student journals both reflected a high degree of student interest and engagement for the contextual lessons. The contextual lessons about music motivated students much more than the non-contextual textbook lessons about work and energy. The music context tapped into student prior knowledge and it was a context that students could easily relate and connect to. The student exit slip results indicated that students understood the concepts of electromagnetism since the test results were very high and the high contextual final unit tests also suggested students understood the electromagnetism concepts. Since the students were interested and engaged in the activity of building an electric guitar I believe the contextual lessons motivated the S4 physics students in a meaningful, contextual learning activity that facilitated their deeper understanding of the concepts of electromagnetism.

CHAPTER 6: SUMMARY

6.1 Research Questions One, Two, Three, and Four

In searching for engagement in high school physics using contextual teaching strategies this study determined that students were very engaged by contextual teaching strategies and displayed positive attitudes towards these activities. Students were more intellectually engaged during the contextual lessons and were less intellectually engaged during the non-contextual lessons. Students had the most positive attitudes when describing the contextual lessons as compared to the non-contextual lessons and preferred the contextual lessons. Students found the contextual lessons interesting, not-boring, exciting and they found the lessons fun and engaging. In comparison students had many negative attitudes towards the non-contextual lessons commenting that the lessons were boring, not interesting, confusing, slow and too easy. The level of student understanding of electromagnetism compared to my previous teaching experience increased by some measure but at a minimum at least remained the same. Students were motivated by the contextual lessons and this motivation facilitated their greater understanding of electromagnetism. Student engagement data was triangulated from a number of sources including student generated questions, student journals, student final unit tests and exit slips. Student attitude data was triangulated from student questions, student journals, teacher journals and rotational graffiti activities.

6.2 Implications of the Study

This study provides other physics teachers and specifically other out of field physics teachers with an alternative instructional strategy for teaching electromagnetism that is intellectually engaging to students. As an out of field physics teacher I struggled with the teaching of electromagnetism in the past since the concepts were difficult to teach and students were not motivated or engaged with the traditional textbook teaching approach. Using the electric guitar as a context to engage students, the results of this study discovered that students were highly intellectually engaged. I discovered that students did as well and better than they had done in the past after studying electromagnetism in the contextual manner using the electric guitar. Students were not just motivationally engaged with the activity of building the electric guitar and the electric guitar pickup, students were intellectually engaged.

After the contextual learning activities, students produced questions with a high degree of depth of thought and student journal responses indicated positive student attitudes with respect to the activities. Since this is the last science class many students may take, the significance of the contextual lessons is that students will carry a continued and more informed positive view of science with them into the future. Students indicated that they enjoyed the activities and some students even went so far as to say that building the guitar pickup and electric guitar was the highlight of their school year. The contextual activity is significant because it fosters positive attitudes with and between students when they worked co-operatively in groups to exchange ideas about how to solve the problem of building the electric guitar and electric guitar pickup.

6.3 Limitations of the Study

One of the limitations to this study is that the results may not translate to other physics classrooms since other physics teachers may not be able to properly represent the context of the electric guitar. I have years of experience playing the guitar, I have a passion for the guitar and I am curious about the history of the guitar. The results of this study may only translate to a teacher with a background similar to myself. The contextual lessons that have been developed building an electric guitar and pickup may involve skills and abilities that other teachers may not be able to reproduce even with additional instruction. Although other teachers may not be able to represent the contextual activities, it is my hope that I could design workshops and teacher materials to alleviate this limitation.

Some people may suggest that a limitation to the study is that there was a greater time spent with students using contextual lessons than with students using non-contextual lessons. With the non-contextual lessons being the nature that they are, to increase the number of lessons in the non-contextual approach would be to do the same things over and over again. The non-contextual lessons used one instructional delivery approach, the textbook, while the contextual lessons used many different instructional approaches. The research could easily have included six lessons in the non-contextual approach to match the number of lessons in the contextual approach. However, the increased number of non-contextual lessons would have resulted in the students being even more bored and even more willing to provide negative feedback about the non-contextual lessons.

Another limitation is that the research was carried out an independent high school with only thirty two students. The research may not translate to different class sizes or to schools where the demographics and teaching schedules may be different. Other physics classrooms may not have the materials necessary to carry out the contextual lessons. The guitar and pickup require many teacher hours of preparation to ready the materials for students and this may be beyond the scope and ability of some teachers. Many of the materials such as the magnet wire are difficult to procure and some teachers may not be able to assemble all the materials necessary to proceed with the lessons. In order to remedy this limitation a kit could be developed for physics teachers to buy that included all of the materials necessary for the guitar activities.

Another limitation of this study may be due to the Hawthorne Effect. This effect suggests that changes in participants' behavior during the course of a study may be "related only to the special social situation and social treatment they received.", (Adair, 1984). For this action research study there is a limitation since the teacher was also the researcher. It would be beneficial to have an independent observer in the classroom making notes on the engagement of the students.

6.4 Recommendations for Further Research

The further research that is recommended is to determine if the contextual lessons are reproducible by other teachers. Since the context of building the electric guitar and electric guitar pickup is very personal to me I had very little difficulty teaching the contextual lessons. For this study to be useful to other teachers it must be able to be taught by anyone regardless of their knowledge of music or their knowledge of the electric guitar. The proposed research would involve a number of teachers who had little or no experience with the electric guitar so that the study could determine what modifications or additional information would be required before other teachers could successfully reproduce the contextual activities. Since there are many out of field physics teachers it would be important to be able to provide these teachers with a contextual electromagnetism resource package that could provide engaging contextual learning activities for students that anyone could successfully teach.

Using Stinner's (1994) idea of a large context problem, further research could examine how to use small parts of a large context problem to design a small unit of about six to eight lessons supported by teaching kits. The kits would consist of three different types, a materials kit, a conceptual kit and a historical kit and they would support the teaching of the small context unit. Pre-service teachers could use these kits as part of their teacher training to help design the lessons used during their teaching block. The teaching kits could also be used by teachers to help implement the small context units in their classrooms.

During the analysis of the journal engagement data it was found that the males obtained higher scores than females but that the scores were close. Further research could look at how to increase the engagement of female students. A number of activities should be tried that would specifically engage female students. Using female guitar players or female bands during more of the contextual lessons could increase the engagement of the female students. The history of rock 'n 'roll is male dominated, however in recent years a number of female guitar players such as Bonnie Raitt who could be used as a role model for female students.

Another proposed area of research may involve expanding this study to include more of the electricity and magnetism outcomes from the physics 40S curriculum. Since the single coil pickups on a Fender Stratocaster electric guitar are wired in series and the humbucking pickup on a Gibson Les Paul electric guitar are wired in parallel it would be relatively easy to expand this study to include electric circuits and resistance. In the past I have used resistors and batteries to model series and parallel electric circuits and it would be interesting to use guitar pickups wired in different ways to teach these same concepts. Speakers and microphones work on the same principles as the electric guitar pickup and activities could be designed to incorporate students building these items. Another area that could be researched is how to incorporate the physics 30S waves outcomes using the guitar as a context. The guitar string could be used to teach some of the waves outcomes and the guitar could ultimately be used to teach contextual lessons from both 30S and 40S physics.

Further research should be done to determine how to apply Stinner's (1994) idea of a large context problem (LCP) to the context of the electric guitar and or additional contexts. "Each LCP should be so designed that most of the physics for a particular topic would have to be used for the completion of the problems suggested by the context" (Stinner,1994, p.375). Using additional large contexts, further research could be done to determine how many physics 40S outcomes could be integrated into an instructional strategy. More research needs to be done involving the use of Stinner's large context problem.

The questions framework (Klassen et al, 2011) as a measure of intellectual engagement is an area of research that requires more study. There is very little research about measures of intellectual engagement and it would be beneficial to determine how the questions measure of intellectual engagement correlated with some of other measures in the literature. In this study the engagement data form student generated questions correlated very well with the engagement data from the self reporting of student engagement through their journals. Some of the other measures of engagement include qualitative measures from Parsons and Taylor (2011). These include student surveys, teacher surveys, student written self reports such as portfolios or teacher observed engagement evidence such as interest and enjoyment (Parsons &Taylor, 2011, p.26).

Finally an area of research that would add to the literature on measures of intellectual engagement would be to determine if the questions framework was consistent over different grade levels. This study only looked at the questions framework as a measure of intellectual engagement for physics 40S classes but the measure should be used to determine how it measures intellectual engagement over the early, middle and senior years.

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Appendix A: Administrator Letter of Recruitment

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Administrator Letter of Recruitment

Research Project Title: In Search of Student Engagement in High School Physics Through Contextual Teaching.

Principal Investigator: Michael Lukie, The University of Winnipeg Collegiate, 515 Portage Ave., Winnipeg, MB, R3B 2E9. 786.9206, m.lukie@uwinnipeg.ca

Research Supervisor: Don Metz, Faculty of Education, The University of Winnipeg, Winnipeg, MB, R3B 2E9.
786.9098, d.metz@uwinnipeg.ca

Dear Administrator,

I am completing my Master's degree in Education at the University of Manitoba and I am conducting research for my thesis in partial fulfillment of the requirements for the degree. I am seeking your permission to approach students in both of my grade twelve physics classes to participate in my research.

The purpose of the research is to compare two teaching strategies. The first strategy will use a textbook to teach the physics concepts of Work for the grade twelve physics mechanics unit. The second method will involve a contextual teaching approach where students build an electric guitar pickup and a simple electric guitar in order to provide a context to teach the physics concepts of electromagnetism for the grade twelve physics electricity unit. I am interested in comparing the student intellectual engagement between the non-contextual and contextual teaching approaches and the degree to which they are engaged in learning, their attitudes to the different instructional methods, and the extent to which their learning has benefited from creating an electromagnetic pickup and guitar as a contextually based activity. To measure the intellectual engagement of students I will collect student generated questions following different instructional activities. The questions will be categorized and ranked to judge the degree of student engagement and depth of thought using a framework where numerical values are assigned to questions which are either factual, conceptual, philosophical or peripheral in nature.

The students will take part in eight lessons. Two lessons will use a textbook to teach the physics concepts of Work and six lessons will involve an activity where electromagnetism is taught using the construction of a guitar pickup. Students will be asked on eleven occasions to write questions they may have regarding the lessons and they will be asked on six occasions to write in a journal about their attitudes towards the lessons. Additionally, I would like to collect the following regular classroom activities; two brainstorming activities called rotational graffiti, two single question tests called exit slips, and two short cumulative tests on the work lessons and on the electromagnetism lessons. All of the documents the students produce will be collected in a portfolio and the students will not put their names on any of these documents, the students will only put their name on the outside of the portfolio. It needs to be made clear that everyone will be taking part in these activities as part of regular classroom instruction. What I am asking for is permission to use the documents the students will produce during the eight lessons as part of the data for my thesis after the physics course has been completed in April. Students will benefit from the research since the building of the guitar pickup will engage them in activities that are connected very closely to their musical interests as teenagers.

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Administrator Letter of Recruitment

There is a risk to participants since I am in a position of power over the participants as their teacher. I am aware of this risk and have taken measures to ensure anonymity. I will only analyze the research data after the final grades have been assigned in April so that the final grades are not biased by the research I am conducting or by the participation of the students. The list of students who consent to participate will be kept with you and kept strictly confidential by locking it in a secure cabinet in the office. After final grades have been assigned in April the portfolios will be given to you and if the student did not provide consent to participate, their portfolio will be shredded and destroyed. If the student did provide consent their portfolio would have their name cut off of it so that it is now anonymous. I will then be given the anonymous portfolios by the administration so that the data may be analyzed.

I order to recruit students I am asking that you delegate a person not in a perceived position of authority to the students to read a summary of the intended research to them. The letter will explain what the research is about and what their participation in the research means. I suggest a secretary may be a good choice for this task.
I will be providing a letter of consent to you shortly which will provide further information and the recruitment text I am asking the delegate to read. I would appreciate your participation with my study.

Thank you.

Appendix B: Administrator Letter of Consent

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Administrator Letter of Consent

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Principal Investigator: Michael Lukie, The University of Winnipeg Collegiate, 515 Portage Ave., Winnipeg, MB, R3B 2E9. 786.9206, m.lukie@uwinnipeg.ca

Research Supervisor: Don Metz, Faculty of Education, The University of Winnipeg, Winnipeg, MB, R3B 2E9.
786.9098, d.metz@uwinnipeg.ca

Dear Administrator,

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what allowing the students at the Collegiate to participate in will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

I am completing my Master's degree in Education at the University of Manitoba and I am conducting research for my thesis in partial fulfillment of the requirements for the degree. I am seeking your permission to approach students in both of my grade twelve physics classes to participate in my research. The purpose of the research is to compare two teaching strategies. The first strategy will be a non-contextual teaching approach using a textbook to teach the physics concepts of Work. The second method will involve a contextual teaching approach where the students will build an electric guitar pickup and a simple electric guitar in order to provide a context to teach the physics concepts of electromagnetism. I am interested in comparing student intellectual engagement between the non-contextual and contextual teaching approaches and the degree to which they are engaged in learning, their attitudes to the different instructional methods, and the extent to which their learning has benefited from creating an electromagnetic pickup and guitar as a contextually based activity. To measure student intellectual engagement I will collect questions from them that they will write following different instructional activities. The questions will be categorized and ranked to judge the degree of their engagement and depth of thought.

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Fax (204) 474-7550

Administrator Letter of Consent

Since I am the students' teacher there is a risk to them as participants since I am in a position of power over them. I am aware of this risk and have taken measures to ensure that the student data remains anonymous. I will only analyze the research data after the final grades have been assigned in April so that the final grades are not biased by the research I am conducting or by the participation of the students. To ensure anonymity, the following protocol must be followed:

1) After the consent letters have come into the office make a list of students who consent and make a list of students who do not consent to participate.
   - In the event that a parent provides consent and a student does not provide assent or in the event that a student provides assent and a parent does not provide consent, this student name will be added to the list of students who will not be participating in the study and whose data will not be used. This list must be kept strictly confidential by locking it in a secure cabinet in the office.
   - In the event that a student should suddenly drop out of the study their name will be added to the list of students who are not providing consent and their portfolio including all documents must be shredded and disposed of

2) After final grades have been assigned in April you will be given all the portfolios that have been stored in a locked cabinet in the classroom. Remove the portfolios of the students who have not given consent, shred them, and dispose of them.

3) Cut the names off the remaining portfolios

4) Give the researcher the anonymous portfolios so that the data may be analyzed.

The student data will not contain any identifying information and this material will be stored in a locked filing cabinet where only I will have access to the information. The material will be stored for the duration of the study and then shredded by October 2012. When completed, the research may be presented to professional audiences and may be written about in professional journals. You will have the opportunity to receive a summary of the research findings upon completion if you wish by October 2012.

I order to recruit students I am asking that you delegate a person not in a perceived position of authority to the students to read a summary of the intended research to them. The letter will explain what the research is about and what their participation in the research means. I suggest a secretary may be a good choice for this task. I have provided this letter immediately following this letter of consent.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project. In no way does this waive your legal rights nor release the researcher, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw your consent from the study at any time, without prejudice or consequence. You should feel free to ask for clarification or new information throughout the research project.

UNIVERSITY OF MANITOBA

Faculty of Education
Department of Curriculum, Teaching and Learning

230 Education Building
University of Manitoba
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9014
Fax (204) 474-7550

Administrator Letter of Consent

The University of Manitoba Research Ethics Board(s) and a representative(s) of the University of Manitoba Research Quality Management / Assurance office may also require access to the research data for safety and quality assurance purposes.

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122. A copy of this consent form has been given to you to keep for your records and reference.

Please check: ____________ I allow The University of Winnipeg Collegiate Students to be used in the research.

Name of Administrator (please print)____

Administrator's
Signature:____Date:________________

Researcher's
Signature:____Date:________________

Please check: ____________ I would like to receive a copy of a summary of the results of this study.

This summary can be sent to:

UNIVERSITY OF MANITOBA

Faculty of Education
Department of Curriculum, Teaching and Learning

230 Education Building
University of Manitoba
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9014
Fax (204) 474-7550

Administrator Letter of Consent

The following text will be read by an individual not in a position of perceived authority to the students as a means of first contact to students. Please read the following:

Letter of First Contact

Mr. Lukie is conducting research for his master's degree thesis and is requesting your participation. He is asking your permission to use the data he collects from you for his thesis analysis. The purpose of the research is to compare two teaching strategies. The first strategy will be a non-contextual teaching approach using a textbook to teach the physics concepts of Work. The second method will involve a contextual teaching approach where you will build an electric guitar pickup and a simple electric guitar in order to provide a context to teach the physics concepts of electromagnetism. He is interested in comparing your intellectual engagement between the non-contextual and contextual teaching approaches and the degree to which you are engaged in learning, your attitudes to the different instructional methods, and the extent to which your learning has benefited from creating an electromagnetic pickup and guitar as a contextually based activity. To measure your intellectual engagement he will collect questions from you that you write following different instructional activities. The questions will be categorized and ranked to judge the degree of your engagement and depth of thought.

You will take part in eight lessons. Two lessons will use a textbook to teach the physics concepts of Work and six lessons will involve an activity where electromagnetism is taught using the construction of a guitar pickup. You will be asked on eleven occasions to write questions you may have regarding the lessons and you will be asked on six occasions to write in a journal about your attitudes towards the lessons. Additionally, Mr. Lukie would like to collect the following regular classroom activities; two brainstorming activities called rotational graffiti, two single question tests called exit slips, and two short cumulative tests on the work lessons and on the electromagnetism lessons. All of the documents you produce will be collected in a portfolio and you will not put your name on any of these documents, you will only put your name on the outside of the portfolio. It needs to be made clear that everyone will be taking part in these activities as part of regular classroom instruction. What Mr. Lukie is asking for is your permission to use the documents you produce during the eight lessons as part of the data for his thesis after the physics course has been completed in April. You will benefit from the research since the building of the guitar pickup will engage you in activities that are connected very closely to your musical interests as teenagers.

Since Mr. Lukie is your teacher there is a risk to you as a participant since he is in a position of power over you. He is aware of this risk and has taken measures to ensure that your data remains anonymous. Mr. Lukie will only analyze the research data after your final grades have been assigned in April so that your final grades are not biased by the research he is conducting or by your participation. The list of students who consent to participate will be kept with the school administration and kept strictly confidential by locking it in a secure cabinet in the office. After final grades have been assigned in April your portfolios will be given to administration and if you did not provide consent, your portfolio will be shredded and destroyed. If you did provide consent your portfolio will have your name cut off of it so that it is now anonymous. Mr. Lukie will then be given the anonymous portfolios so that the data may be analyzed.

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Fax (204) 474-7550

Administrator Letter of Consent

Your student data will not contain any identifying information and this material will be stored in a locked filing cabinet where only he will have access to the information. The material will be stored for the duration of the study and then shredded by October 2012. When completed, the research may be presented to professional audiences and may be written about in professional journals. You will have the opportunity to receive a summary of the research findings upon completion if you wish by October 2012. You may withdraw your consent at anytime during the study by verbally informing the school administration or by calling the secretary at 786-9221. Your portfolio including all documents generated will then be shredded and disposed of at that time.

I will now hand out letters for you to indicate whether or not you would like to participate in the research. For those students who are over 18 you have one letter to fill out, a letter of consent. For those students who are under 18 you will be required to fill out two letters, a letter of assent that you must fill out and a letter of consent that your parent(s)/legal guardian must fill out. Giving your assent means that you agree to something after your thoughtful consideration. Since some of you are under the age of 18 your legal guardian must still give their consent or their legal permission allowing you to participate in the study even though you may give your assent.

When you have the letters signed, please return them to the secretary in the main office of the Collegiate. Mr. Lukie looks forward to working with you. Thank you.

Appendix C: Letter to Student

Please read the following:

Mr. Lukie is conducting research for his master's degree thesis and is requesting your participation. He is asking your permission to use the data he collects from you for his thesis analysis. The purpose of the research is to compare two teaching strategies. The first strategy will be a non-contextual teaching approach using a textbook to teach the physics concepts of Work. The second method will involve a contextual teaching approach where you will build an electric guitar pickup and a simple electric guitar in order to provide a context to teach the physics concepts of electromagnetism. He is interested in comparing your intellectual engagement between the non-contextual and contextual teaching approaches and the degree to which you are engaged in learning, your attitudes to the different instructional methods, and the extent to which your learning has benefited from creating an electromagnetic pickup and guitar as a contextually based activity. To measure your intellectual engagement he will collect questions from you that you write following different instructional activities. The questions will be categorized and ranked to judge the degree of your engagement and depth of thought.

You will take part in eight lessons. Two lessons will use a textbook to teach the physics concepts of Work and six lessons will involve an activity where electromagnetism is taught using the construction of a guitar pickup. You will be asked on eleven occasions to write questions you may have regarding the lessons and you will be asked on six occasions to write in a journal about your attitudes towards the lessons. Additionally, Mr. Lukie would like to collect the following regular classroom activities; two brainstorming activities called rotational graffiti, two single question tests called exit slips, and two short cumulative tests on the work lessons and on the electromagnetism lessons. All of the documents you produce will be collected in a portfolio and you will not put your name on any of these documents, you will only put your name on the outside of the portfolio. It needs to be made clear that everyone will be taking part in these activities as part of regular classroom instruction. What Mr. Lukie is asking for is your permission to use the documents you produce during the eight lessons as part of the data for his thesis after the physics course has been completed in April. You will benefit from the research since the building of the guitar pickup will engage you in activities that are connected very closely to your musical interests as teenagers.

Since Mr. Lukie is your teacher there is a risk to you as a participant since he is in a position of power over you. He is aware of this risk and has taken measures to ensure that your data remains anonymous. Mr. Lukie will only analyze the research data after your final grades have been assigned in April so that your final grades are not biased by the research he is conducting or by your participation. The list of students who consent to participate will be kept with the school administration and kept strictly confidential by locking it in a secure cabinet in the office. After final grades have been assigned in April your portfolios will be given to administration and if you did not provide consent, your portfolio will be shredded and destroyed. If you did provide consent your portfolio will have your name cut off of it so that it is now anonymous. Mr. Lukie will then be given the anonymous portfolios so that the data may be analyzed.

Your student data will not contain any identifying information and this material will be stored in a locked filing cabinet where only he will have access to the information. The material will be stored for the duration of the study and then shredded by October 2012. When completed, the research may be presented to professional audiences and may be written about in professional journals. You will have the opportunity to receive a summary of the research findings upon completion if you wish by October 2012. You may withdraw your consent at anytime during the study by verbally informing the school administration or by calling the secretary at 786-9221. Your portfolio including all documents generated will then be shredded and disposed of at that time.

I will now hand out letters for you to indicate whether or not you would like to participate in the research. For those students who are over 18 you have one letter to fill out, a letter of consent. For those students who are under 18 you will be required to fill out two letters, a letter of assent that you must fill out and a letter of consent that your parent(s)/legal guardian must fill out. Giving your assent means that you agree to something after your thoughtful consideration. Since some of you are under the age of 18 your legal guardian must still give their consent or their legal permission allowing you to participate in the study even though you may give your assent. When you have the letters signed, please return them to the secretary in the main office of the Collegiate. Mr. Lukie looks forward to working with you. Thank you.

Appendix D: Student Letter of Assent (for students under 18)

UNIVERSITY OF MANITOBA | Faculty of Education
Department of Curriculum, Teaching and Learning

230 Education Building
University of Manitoba
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9014
Fax (204) 474-7550

Student Letter of Assent (for students under 18)

Research Project Title: In Search of Student Engagement in High School Physics Through Contextual Teaching.

Principal Investigator: Michael Lukie, The University of Winnipeg Collegiate, 515 Portage Ave., Winnipeg, MB, R3B 2E9. 786.9206, m.lukie@uwinnipeg.ca

Research Supervisor: Don Metz, Faculty of Education, The University of Winnipeg, Winnipeg, MB, R3B 2E9.
786.9098, d.metz@uwinnipeg.ca

Dear Student,

This assent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information. Giving your assent means that you agree to something after your thoughtful consideration. Since you are under the age of 18 your parent(s)/legal guardian must still give their consent or their legal permission allowing you to participate in the study even though you have given your assent.

I am conducting research for my Master's degree thesis and I am requesting your participation. I am asking your permission to use the data I collect from you for my thesis analysis. The purpose of the research is to compare two teaching strategies. The first strategy will be a non-contextual teaching approach using a textbook to teach the physics concepts of Work. The second method will involve a contextual teaching approach where you will build an electric guitar pickup and a simple electric guitar in order to provide a context to teach the physics concepts of electromagnetism. I am interested in comparing your intellectual engagement between the non-contextual and contextual teaching approaches and the degree to which you are engaged in learning, your attitudes to the different instructional methods, and the extent to which your learning has benefited from creating an electromagnetic pickup and guitar as a contextually based activity. To measure your intellectual engagement I will collect questions from you that you write following different instructional activities. The questions will be categorized and ranked to judge the degree of your engagement and depth of thought.

You will take part in eight lessons. Two lessons will use a textbook to teach the physics concepts of Work and six lessons will involve an activity where electromagnetism is taught using the construction of a guitar pickup. You will be asked on eleven occasions to write questions you may have regarding the lessons and you will be asked on six occasions to write in a journal about your attitudes towards the lessons. Additionally, I would like to collect the following regular classroom activities; two brainstorming activities called rotational graffiti, two single question tests called exit slips, and two short cumulative tests on the work lessons and on the electromagnetism lessons. All of the documents you produce will be collected in a portfolio and you will not put your name on any of these documents, you will only put your name on the outside of the portfolio. It needs to be made clear that everyone will be taking part in these activities as part of regular classroom instruction. What I am asking for is your permission to use the documents you produce during the eight lessons as part of the data for my thesis after the course has been

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Fax (204) 474-7550

Student Letter of Assent (for students under 18)

completed in April. You will benefit from the research since the building of the guitar pickup will engage you in activities that are connected very closely to your musical interests as teenagers.

Since I am your teacher there is a risk to you as a participant since I am in a position of power over you. I am aware of this risk and have taken measures to ensure that your data remains anonymous. I will only analyze the research data after your final grades have been assigned in April so that your final grades are not biased by the research I am conducting or by your participation. The list of students who consent to participate will be kept with the school administration and kept strictly confidential by locking it in a secure cabinet in the office. In the event that your legal guardian provides consent and you do not provide assent or in the event that you provide assent and your legal guardian does not provide consent, your name will be added to the list of students who will not be participating in the study and whose data will not be used. After final grades have been assigned in April your portfolios will be given to administration and if you did not provide consent, your portfolio will be shredded and destroyed. If you did provide consent your portfolio will have your name cut off of it so that it is now anonymous. I will then be given the anonymous portfolios so that the data may be analyzed.

Your student data will not contain any identifying information and this material will be stored in a locked filing cabinet where only I will have access to the information. The material will be stored for the duration of the study and then shredded by October 2012. When completed, the research may be presented to professional audiences and may be written about in professional journals. You will have the opportunity to receive a summary of the research findings upon completion if you wish by October 2012. You may withdraw your assent at anytime during the study by verbally informing the school administration or by calling the secretary at 786-9221. Your portfolio including all documents generated will then be shredded and disposed of at that time.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researcher, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial assent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba Research Ethics Board(s) and a representative(s) of the University of Manitoba Research Quality Management / Assurance office may also require access to the research data for safety and quality assurance purposes.

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122. A copy of this consent form has been given to you to keep for your records and reference.

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Fax (204) 474-7550

Student Letter of Assent (for students under 18)

Please check: ____________ I agree to participate in the study described above. **(I am under 18)**

Name of student (please print): ____

Student's
Signature:____Date:_______________

Researcher's
Signature:____Date:________________

Please check: ____________ I would like to receive a copy of a summary of the results of this study.

This summary can be sent to:

Appendix E: Parent Letter of Consent (for students under 18)

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Department of Curriculum, Teaching and Learning

230 Education Building
University of Manitoba
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9014
Fax (204) 474-7550

Parent Letter of Consent (for students under 18)

Research Project Title: In Search of Student Engagement in High School Physics Through Contextual Teaching.

Principal Investigator: Michael Lukie, The University of Winnipeg Collegiate, 515 Portage Ave., Winnipeg, MB, R3B 2E9. 786.9206, m.lukie@uwinnipeg.ca

Research Supervisor: Don Metz, Faculty of Education, The University of Winnipeg, Winnipeg, MB, R3B 2E9.
786.9098, d.metz@uwinnipeg.ca

Dear Parent,

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what allowing your son/daughter to participate in will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

I am conducting research for my Master's degree thesis and I am requesting your permission to use your son/daughter (student) as a participant in my research project. I am asking your permission to allow me to use the data I collect from them for my thesis analysis. The purpose of the research is to compare two teaching strategies. The first strategy will be a non-contextual teaching approach using a textbook to teach the physics concepts of Work. The second method will involve a contextual teaching approach where the students will build an electric guitar pickup and a simple electric guitar in order to provide a context to teach the physics concepts of electromagnetism. I am interested in comparing student intellectual engagement between the non-contextual and contextual teaching approaches and the degree to which they are engaged in learning, their attitudes to the different instructional methods, and the extent to which their learning has benefited from creating an electromagnetic pickup and guitar as a contextually based activity. To measure student intellectual engagement I will collect questions from them that they will write following different instructional activities. The questions will be categorized and ranked to judge the degree of their engagement and depth of thought.

The students will take part in eight lessons. Two lessons will use a textbook to teach the physics concepts of Work and six lessons will involve an activity where electromagnetism is taught using the construction of a guitar pickup. Students will be asked on eleven occasions to write questions they may have regarding the lessons and they will be asked on six occasions to write in a journal about their attitudes towards the lessons. Additionally, I would like to collect the following regular classroom activities; two brainstorming activities called rotational graffiti, two single question tests called exit slips, and two short cumulative tests on the work lessons and on the electromagnetism lessons. All of the documents the students produce will be collected in a portfolio and the students will not put their names on any of these documents, the students will only put their name on the outside of the portfolio. It needs to be made clear that everyone will be taking part in these activities as part of regular classroom instruction. What I am asking for is permission to use the documents the students will produce during the eight lessons as part of the data for my thesis after the physics course has been completed in April. Students will benefit from the

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Department of Curriculum, Teaching and Learning

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Telephone (204) 474-9014
Fax (204) 474-7550

Parent Letter of Consent (for students under 18)

research since the building of the guitar pickup will engage them in activities that are connected very closely to their musical interests as teenagers.

Since I am the students' teacher there is a risk to them as participants since I am in a position of power over them. I am aware of this risk and have taken measures to ensure that the student data remains anonymous. I will only analyze the research data after the final grades have been assigned in April so that the final grades are not biased by the research I am conducting or by the participation of the students. The list of students who consent to participate will be kept with the school administration and kept strictly confidential by locking it in a secure cabinet in the office. After final grades have been assigned in April the student portfolios will be given to administration and if the student did not provide consent, the portfolio will be shredded and destroyed. If the student did provide consent the portfolio will have the student name cut off of it so that it is now anonymous. I will then be given the anonymous portfolios so that the data may be analyzed.

The student data will not contain any identifying information and this material will be stored in a locked filing cabinet where only I will have access to the information. The material will be stored for the duration of the study and then shredded by October 2012. When completed, the research may be presented to professional audiences and may be written about in professional journals. You will have the opportunity to receive a summary of the research findings upon completion if you wish by October 2012. You may withdraw your consent to allow your son/daughter to participate at anytime during the study by verbally informing the school administration or by calling the secretary at 786-9221. The student's portfolio including all documents generated will then be shredded and disposed of at that time.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project. In no way does this waive your legal rights nor release the researcher, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw your son/daughter from the study at any time, without prejudice or consequence. Y ou should feel free to ask for clarification or new information throughout the research project.

The University of Manitoba Research Ethics Board(s) and a representative(s) of the University of Manitoba Research Quality Management / Assurance office may also require access to the research data for safety and quality assurance purposes.

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122. A copy of this consent form has been given to you to keep for your records and reference.

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Winnipeg, Manitoba
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Telephone (204) 474-9014
Fax (204) 474-7550

Parent Letter of Consent (for students under 18)

Please check: _____________ I agree to allow my son/daughter to participate in the research. **(Student under 18)**

Name of student (please print): ____

Parent's
Signature:____Date:________________

Researcher's
Signature:____Date:__________________

Please check: _____________ I would like to receive a copy of a summary of the results of this study.

This summary can be sent to:

Appendix F: Student Letter of Consent (for students over 18)

UNIVERSITY OF MANITOBA
Faculty of Education
Department of Curriculum, Teaching and Learning

230 Education Building
University of Manitoba
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9014
Fax (204) 474-7550

Student Letter of Consent (for students over 18)

Research Project Title: In Search of Student Engagement in High School Physics Through Contextual Teaching.

Principal Investigator: Michael Lukie, The University of Winnipeg Collegiate, 515 Portage Ave., Winnipeg, MB, R3B 2E9. 786.9206, m.lukie@uwinnipeg.ca

Research Supervisor: Don Metz, Faculty of Education, The University of Winnipeg, Winnipeg, MB, R3B 2E9.
786.9098, d.metz@uwinnipeg.ca

Dear Student,

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

I am conducting research for my Master's degree thesis and I am requesting your participation. I am asking your permission to use the data I collect from you for my thesis analysis. The purpose of the research is to compare two teaching strategies. The first strategy will be a non-contextual teaching approach using a textbook to teach the physics concepts of Work. The second method will involve a contextual teaching approach where you will build an electric guitar pickup and a simple electric guitar in order to provide a context to teach the physics concepts of electromagnetism. I am interested in comparing your intellectual engagement between the non-contextual and contextual teaching approaches and the degree to which you are engaged in learning, your attitudes to the different instructional methods, and the extent to which your learning has benefited from creating an electromagnetic pickup and guitar as a contextually based activity. To measure your intellectual engagement I will collect questions from you that you write following different instructional activities. The questions will be categorized and ranked to judge the degree of your engagement and depth of thought.

You will take part in eight lessons. Two lessons will use a textbook to teach the physics concepts of Work and six lessons will involve an activity where electromagnetism is taught using the construction of a guitar pickup. You will be asked on eleven occasions to write questions you may have regarding the lessons and you will be asked on six occasions to write in a journal about your attitudes towards the lessons. Additionally, I would like to collect the following regular classroom activities; two brainstorming activities called rotational graffiti, two single question tests called exit slips, and two short cumulative tests on the work lessons and on the electromagnetism lessons. All of the documents you produce will be collected in a portfolio and you will not put your name on any of these documents, you will only put your name on the outside of the portfolio. It needs to be made clear that everyone will be taking part in these activities as part of regular classroom instruction. What I am asking for is your permission to use the documents you produce during the eight lessons as part of the data for my thesis after the course has been completed in April. You will benefit from the research since the building of the guitar pickup will engage you in activities that are connected very closely to your musical interests as teenagers.

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Department of Curriculum, Teaching and Learning

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University of Manitoba
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9014
Fax (204) 474-7550

Student Letter of Consent (for students over 18)

Since I am your teacher there is a risk to you as a participant since I am in a position of power over you. I am aware of this risk and have taken measures to ensure that your data remains anonymous. I will only analyze the research data after your final grades have been assigned in April so that your final grades are not biased by the research I am conducting or by your participation. The list of students who consent to participate will be kept with the school administration and kept strictly confidential by locking it in a secure cabinet in the office. After final grades have been assigned in April your portfolios will be given to administration and if you did not provide consent, your portfolio will be shredded and destroyed. If you did provide consent your portfolio will have your name cut off of it so that it is now anonymous. I will then be given the anonymous portfolios so that the data may be analyzed.

Your student data will not contain any identifying information and this material will be stored in a locked filing cabinet where only I will have access to the information. The material will be stored for the duration of the study and then shredded by October 2012. When completed, the research may be presented to professional audiences and may be written about in professional journals. You will have the opportunity to receive a summary of the research findings upon completion if you wish by October 2012. You may withdraw your consent at anytime during the study by verbally informing the school administration or by calling the secretary at 786-9221. Your portfolio including all documents generated will then be shredded and disposed of at that time.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researcher, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba Research Ethics Board(s) and a representative(s) of the University of Manitoba Research Quality Management / Assurance office may also require access to the research data for safety and quality assurance purposes.

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122. A copy of this consent form has been given to you to keep for your records and reference.

University of Manitoba

Faculty of Education
Department of Curriculum, Teaching and Learning

230 Education Building
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Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9014
Fax (204) 474-7550

Student Letter of Consent (for students over 18)

Please check: _____________ I agree to participate in the study described above. **(I am over 18)**

Name of student (please print): ____

Student's
Signature:____Date:________________

Researcher's
Signature:____Date:_________________

Please check: _____________ I would like to receive a copy of a summary of the results of this study.

This summary can be sent to:

Appendix G: Research Ethics Approval Certificate

Human Ethics
208 - 194 Dafoe Road
Winnipeg, MB
Canada R3T 2N2 Fax
204-269-7173

UNIVERSITY OF MANITOBA

Office of the Vice-President
(Research and International)
Research Ethics and **Compliance**

APPROVAL CERTIFICATE

January 13, 2012

TO: **Michael Lukie** (Advisor D. Metz)
Principal Investigator

FROM: **Stan Straw, Chair**
Education/Nursing Research Ethics Board (ENREB)

Re: **Protocol #E2011:118**
"In Search of Student Engagement in High School Physics through Contextual Teaching"

Please be advised that your above-referenced protocol has received human ethics approval by the **Education/Nursing Research Ethics Board,** which is organized and operates according to the Tri-Council Policy Statement (2). This approval is valid for one year only.

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

Please note:

- **If you have funds pending human ethics approval, the auditor requires that you submit a copy of this Approval Certificate to the Office of Research Services, fax 261-0325 - please include the name of the funding agency and your UM Project number. This must be faxed before your account can be accessed.**
- **if you have received multi-year funding for this research, responsibility lies with you to apply for and obtain Renewal Approval at the expiry of the initial one-year approval; otherwise the account will be locked.**

The Research Quality Management Office may request to review research documentation from this project to demonstrate compliance with this approved protocol and the University of Manitoba Ethics of Research Involving Humans.

The Research Ethics Board requests a final report for your study (available at: http://umanitoba.ca/research/ors/ethics/ors_ethics_human_REBforms_guidelines.html) **in order to be in compliance with Tri-Council Guidelines.**

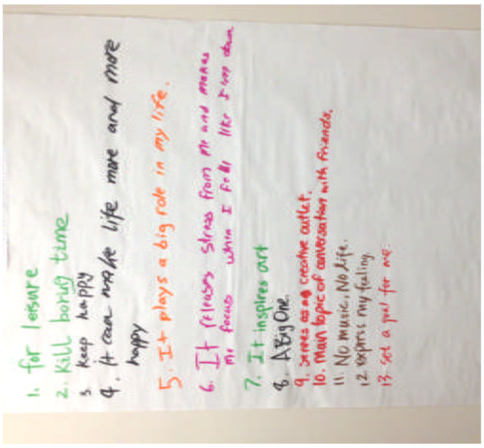
Appendix H: Non-contextual Rotational Graffiti


T/Th
(1) Write what you know about energy.
(2) Write what you know about force.
(3) Draw things you push or pull.
M/W/F
(1) Write what you know about energy.
(2) Write what you know about force.
(3) Draw things you push or pull.

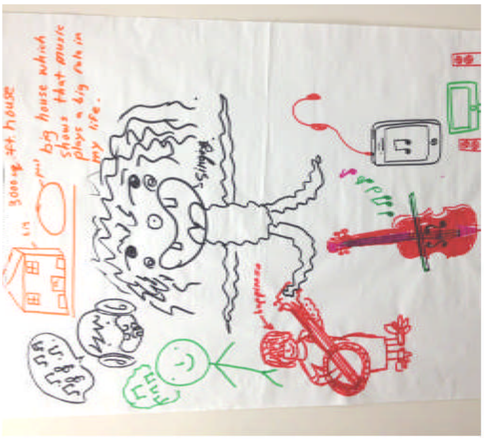
Appendix I: Contextual Rotational Graffiti

M/W/F

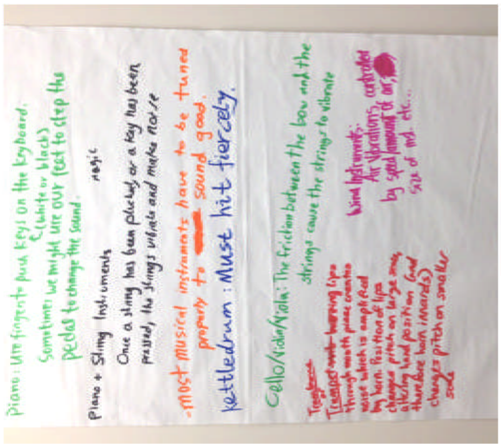
(1) Write-what role does music play in your life?



(2) Draw-What role does music play in your life?



(3) Write-How do musical instruments work?



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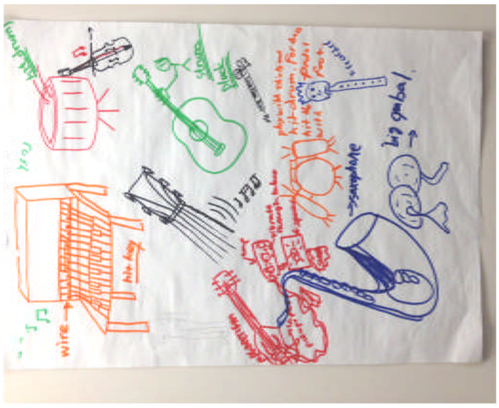
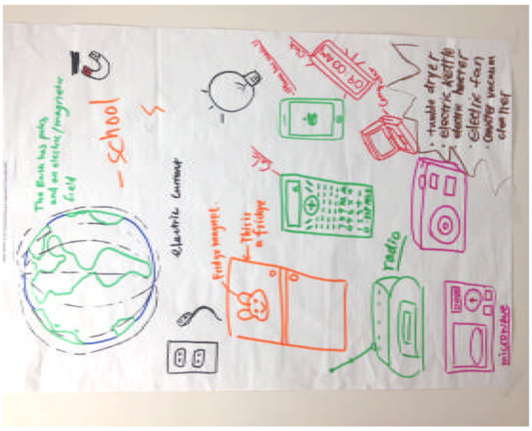
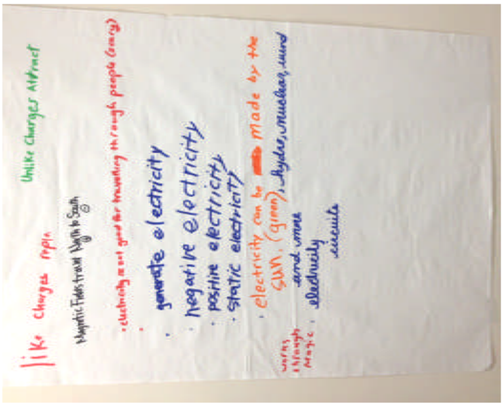


M/W/F



(5) Write-Where do you find electricity and magnetism in your daily life?

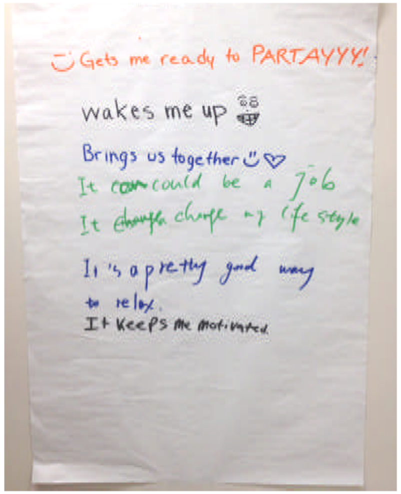


(6) Write-Explain about electricity and magnetism?

(7) Draw-Explain about electricity and magnetism?

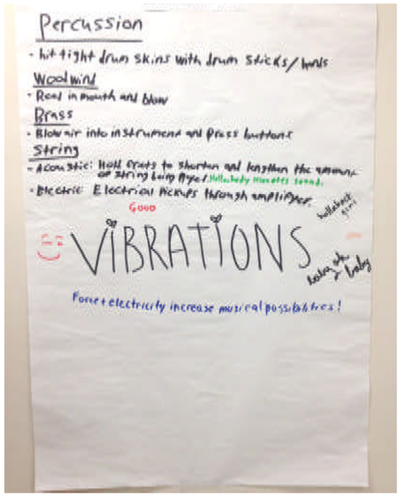
T/Th

(1) Write-what role does music play in your life?



(2) Draw-What role does music play in your life?

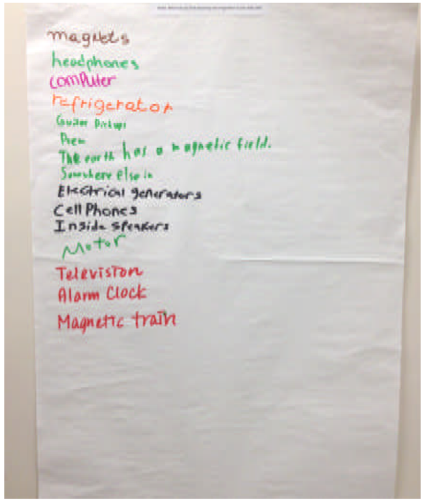
(3) Write-How do musical instruments work?



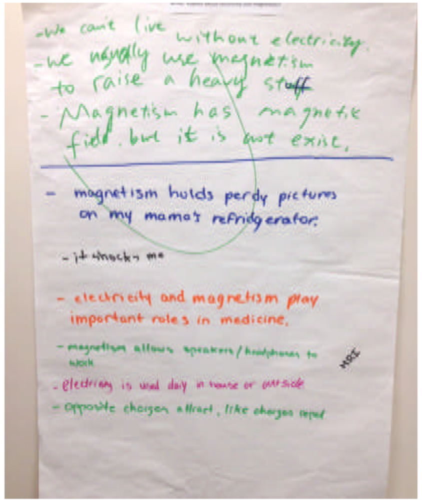
(4) Draw-How do musical instruments work?

T/Th

(5) Write-Where do you find electricity and magnetism in your daily life?



(6) Write-Explain about electricity and magnetism?



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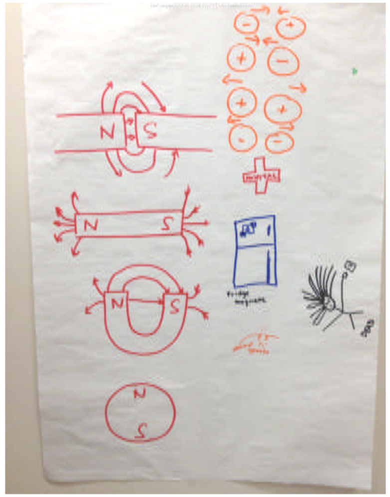


Appendix J: Exit Slip Flux and Solutions

Magnetic Flux Exit Slip
Contextual Teaching Lesson 3: Magnetic Flux and Induced EMF

Date:______________________, 2012

A magnetic field of $5.4x10^{-5}$T passes through a circular coil of diameter 15.2 cm at an angle of 30°. What is the magnetic flux through the coil?

Magnetic Flux Exit Slip
Contextual Teaching Lesson 3: Magnetic Flux and Induced EMF

Date:____________________, 2012

A magnetic field of 5.4×10^{-5}T passes through a circular coil of diameter 15.2 cm at an angle of 30°. What is the magnetic flux through the coil?

$\vec{B} = 5.4 \times 10^{-5}\ T$

$d = 15.2\ cm = .152\ m$

$\theta = 30^\circ$

$\Phi = ?$

$A = \pi r^2$

$= \pi \left(\frac{d}{2}\right)^2$

$= \pi \left(\frac{.152}{2}\right)^2$

$\Phi = \vec{B} A \cos\theta$

$= 5.4 \times 10^{-5}\ \pi \left(\frac{.152}{2}\right)^2 \cos 30^\circ$

$= 5.4 \times 10^{-5}\ \pi \left(\frac{.152}{2}\right)^2 \frac{\sqrt{3}}{2}$

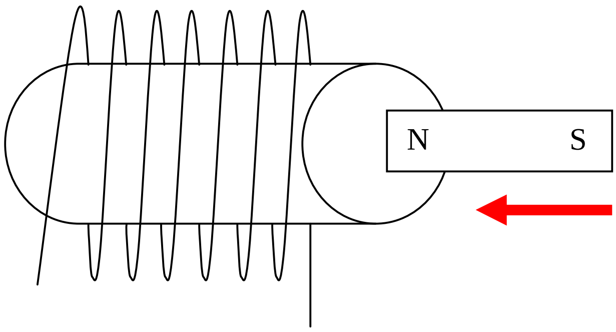
$= 8.486 \times 10^{-7}\ Wb.$

Appendix K: Exit Slip Lenz's Law and Solutions

Lenz's Law Exit Slip
Contextual Teaching Lesson 4: Lenz's Law, Faradays Law & Guitar Pickup Physics

Date:______________________, 2012

Use Lenz's Law to predict which way the induced current will flow in a coil of wire if the north pole of a magnet is entering a coil of wire.

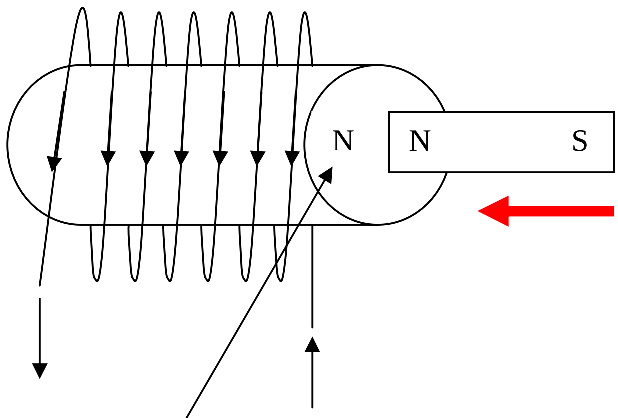


Lenz's Law Exit Slip

Contextual Teaching Lesson 4: Lenz's Law, Faradays Law & Guitar Pickup Physics

Date:______________________, 2012

Use Lenz's Law to predict which way the induced current will flow in a coil of wire if the north pole of a magnet is entering a coil of wire.



Lenz's law predicts that to oppose an incoming north pole of the magnet, a north pole must be induced at the end of the coil here. Using the right hand rule for a solenoid, the thumb points in the direction of the north pole of the solenoid and the fingers curl in the direction of the conventional current flow. This current flow must be counter clockwise to produce the north pole opposing the magnet north pole at the end of the coil.

Appendix L: Non-contextual Unit Test and Solutions

Date:________________, 2012 Total Marks=20

Answer the following questions in the space provided.

[2] **1.** Lee pushes horizontally with a 80 N force on a 20 kg mass 10 m across a floor. Calculate the amount of work Lee did.

[8] **2.** John pushes a crate across the floor of a factory with a horizontal force. The roughness of the floor changes and John must exert a force of 20 N for 5 m, then 35 N for 12m, then 10 N for 8 m.

[5] (a) Draw a graph of force as a function of distance.

[3] (b) Find the work John does pushing the crate.

[3] **3.** Mike pulls a sled across level snow with a force of 225 N along a rope that is 35^0 above the horizontal. If the sled moved a distance of 65.3m, how much work did Mike do?

[3] **4.** An 845 N sled is pulled a distance of 185 m. The task requires $1.20 x 10^4$ J of work and is done by pulling on a rope with a force of 125 N. At what angle is the rope held?

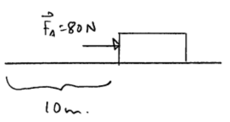
[4] **5.** Describe how an understanding of work and energy can be applied to an example from *your* everyday life.

Non-Contextual Lessons 1&2 Test

Date:________________, 2012 Total Marks=20

Answer the following questions in the space provided.

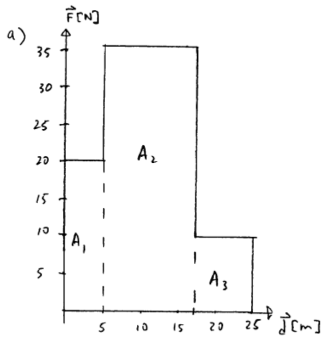
[2] **1.** Lee pushes horizontally with a 80 N force on a 20 kg mass 10 m across a floor. Calculate the amount of work Lee did.



Work : $\vec{F} \cdot \vec{d}$
: 80 · 10
: 800 N·m
: 800 Joules

[8] **2.** John pushes a crate across the floor of a factory with a horizontal force. The roughness of the floor changes and John must exert a force of 20 N for 5 m, then 35 N for 12m, then 10 N for 8 m.
[5] (a) Draw a graph of force as a function of distance.
[3] (b) Find the work John does pushing the crate.

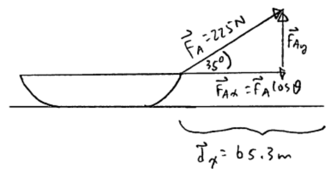
a)



b) Work : Area1 + Area 2 + Area 3
: 5(20) + 12(35) + 8(10)
: 100 + 420 + 80
: 600 Joules.

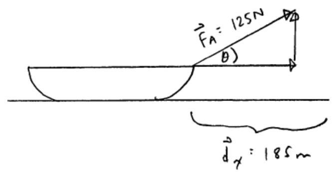
Non-Contextual Lessons 1&2 Test

[3] **3.** Mike pulls a sled across level snow with a force of 225 N along a rope that is 35^0 above the horizontal. If the sled moved a distance of 65.3m, how much work did Mike do?



Work : $\vec{F} \times \vec{d}$
: $\vec{F}_{Ax} \times \vec{d}_x$
: $\vec{F}_A \cos\theta\, \vec{d}_x$
: 225 cos 35° (65.3)
: 12 035.39 Joules

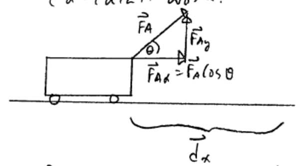
[3] **4.** An 845 N sled is pulled a distance of 185 m. The task requires 1.20×10^4 J of work and is done by pulling on a rope with a force of 125 N. At what angle is the rope held?



Work : $\vec{F} \times \vec{d}$
W = $\vec{F}_{Ax} \vec{d}_x$
W : $\vec{F}_A \cos\theta\, \vec{d}_x$
$\cos\theta = \frac{W}{\vec{F}_A \vec{d}_x}$
$\theta = \cos^{-1}\left(\frac{W}{\vec{F}_A \vec{d}_x}\right)$
$\theta = \cos^{-1}\left(\frac{1.20 \times 10^4}{125(185)}\right)$
θ = 58.74°

[4] **5.** Describe how an understanding of work and energy can be applied to an example from *your* everyday life.

When pulling a shopping cart the horizontal component of the applied force is used to calculate work.



W = $\vec{F}\vec{d}$
: $\vec{F}_{Ax} \vec{d}_x$
= $\vec{F}_A \cos\theta\, \vec{d}_x$ [Joules]

Food energy is converted by muscles in doing work.

Appendix M: Contextual Unit Test and Solutions

Date:________________, 2012 Total Marks=20

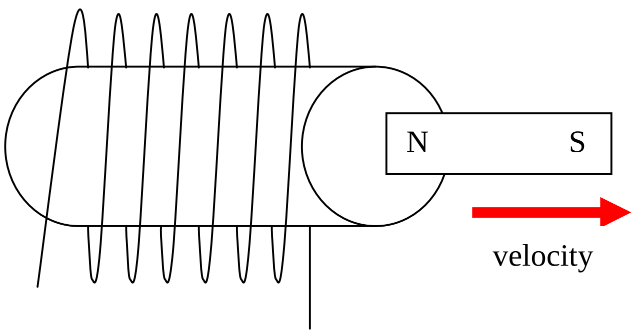
Answer the following questions in the space provided.

[3] **1.** Draw the field lines around 2 bar magnets whose opposite poles are a few centimetres apart.

[3] **2.** A rectangular coil of wire is situated in a constant magnetic field whose magnitude is 2.5T. The coil has dimensions of 1mx2m. Determine the magnetic flux for the following angles:

(a) $\theta=0°$ (b) $\theta=30°$ (c) $\theta=90°$

[4] **3.** Use Lenz's Law to predict which way the induced current will flow in a coil of wire if the north pole of a magnet is leaving a coil of wire. Explain your reasoning and draw the appropriate field lines.



[3] **4.** Describe Faraday's Law of electromagnetic induction and include the formula.

[4] **5.** A coil of wire consists of 20 loops, each of which has an area of 1.5×10^{-3} m^2. A magnetic field is perpendicular to the surface of each loop at all times, so that $\theta = \theta_0 = 0^0$. At time $t_0=0$, the magnitude of the magnetic field at the location of the coil is $\mathbf{B}_0=0.050$ T. At a later time of t=0.10 s, the magnitude of the field at the coil has increased to $\mathbf{B}=0.060$ T. Find the average emf induced in the coil during this time.

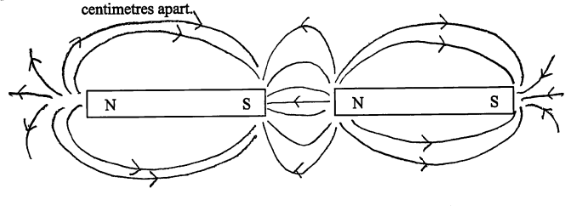
[3] **6.** Describe how an understanding of electromagnetism can be applied to an example from your everyday life.

Contextual Lessons 1 to 4 Electromagnetism Test

Date:_______________, 2012 Total Marks=20

Answer the following questions in the space provided.

[3] **1.** Draw the field lines around 2 bar magnets whose opposite poles are a few centimetres apart.



[3] **2.** A rectangular coil of wire is situated in a constant magnetic field whose magnitude is 2.5T. The coil has dimensions of 1mx2m.Determine the magnetic flux for the following angles: $\vec{B} = 2.5T$ Area : $2m^2$

(a) θ=0°

$\Phi = BA\cos\theta$
$= 2.5(2)\cos 0°$
$= 5\ Wb$

(b) θ=30°

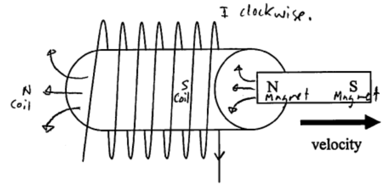
$\Phi = BA\cos\theta$
$= 2.5(2)\cos 30°$
$= 2.5(2)\frac{\sqrt{3}}{2}$
$= 4.33\ Wb.$

(c) θ=90°

$\Phi = BA\cos\theta$
$= 2.5(2)\cos 90°$
$= 0\ Wb.$

[4] **3.** Use Lenz's Law to predict which way the induced current will flow in a coil of wire if the north pole of a magnet is leaving a coil of wire. Explain your reasoning and draw the appropriate field lines.

I clockwise.



Since the original field is decreasing, the induced magnetic flux opposes this change and must increase the flux in the loop. So the magnetic flux due to the induced current must point right to left. to oppose the decreasing left to right movement of the magnet. North pole of coil points left.

Contextual Lessons 1 to 4 Electromagnetism Test

[3] **4.** Describe Faraday's Law of electromagnetic induction and include the formula.

Faraday's law states that the emf induced in a circuit containing a coil of N loops is N times the time rate of change of magnetic flux for the circuit. The magnitude of the induced emf is calculated by the negative of the number of loops times the change in magnetic flux divided by the change in time. $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$ [volts]

[4] **5.** A coil of wire consists of 20 loops, each of which has an area of $1.5 \times 10^{-3}\ m^2$. A magnetic field is perpendicular to the surface of each loop at all times, so that $\theta = \theta_0 = 0^0$. At time $t_0 = 0$, the magnitude of the magnetic field at the location of the coil is $B_0 = 0.050$ T. At a later time of t=0.10 s, the magnitude of the field at the coil has increased to **B**=0.060 T. Find the average emf induced in the coil during this time.

N: 20 loops
A: $1.5 \times 10^{-3}\ m^2$
$\theta = \theta_0 : 0°$
t: 0.1 s.
$\vec{B}_0 : 0.05T$
$\vec{B} : 0.06T$

$V = -N\frac{\Delta\Phi}{\Delta t}$

$= -N\frac{(\Delta B)A\cos\theta}{\Delta t}$

$= \frac{-20(0.06 - 0.05)(1.5 \times 10^{-3})\cos 0°}{0.1}$

$= \frac{-20(.01)(1.5 \times 10^{-3})}{0.1}$

$= -20(.01)(1.5 \times 10^{-3})10$

$= -200(.01)(1.5 \times 10^{-3})$

$= -2(1.5 \times 10^{-3})$

$= -3 \times 10^{-3}$ volts.

[3] **6.** Describe how an understanding of electromagnetism can be applied to an example from your everyday life.

Appendix N: Historical Development of the Electric Guitar

Historical Development of the Electric Guitar

- Some things were invented for obvious reasons but with others the motivation is less clear.
- Consider the invention of the electric guitar.
- When guitarists first crudely electrified their instruments in the 1920's what were they trying to do?
- Why change an instrument that had been successful for hundreds of years?
- The story I will tell you this morning will answer these questions.

1

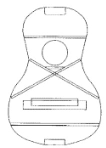
- In the late 1900's music was becoming increasingly more popular with the advent of Big Band Music, radio and the recording industry.
- Performances moved to increasingly larger public spaces and the sizes of the ensembles grew correspondingly.
- Musicians found that they needed more volume.
- Innovations began to be made to the instruments including the guitar in order to increase their volume.

2

Innovations to Increase Acoustic Guitar Volume

- **Innovation 1: X-bracing**
- **developed by Christian Frederick Martin, Sr. in 1850**
- **used as a structural support for the guitar body**

1928 Martin 000-45



- **Innovation 2: Arch Top**
- **developed by Orville Gibson in 1890**
- **Orville gave the guitar a curved arched top as is found on a violin**

Gibson Model: L-4 Acoustic Archtop

3

- **Innovation 3: Coil-wound Non-electromagnetic Pickup**
- **developed in 1923 by a Gibson engineer Lloyd Loar**
- **used the guitar's physical vibrations transmitted through the bridge to vibrate a diaphragm stretched over the pickup to create an electrical signal**

- **Innovation 4: Metal-body Guitar (Dobro)**
- **developed in 1925 by John Dopyera**
- **the metal resonating cones produced aloud, brash tone**
- **1925 the Grand Ole Opry began broadcasting a radio program that became very popular**

- **Innovation 5: Metal Guitar Strings**
- **gut strings were replaced by metal strings**
- **to withstand the tension the guitar body was made larger, more internal bracing was added and the neck was reinforced**
- **1930 Martin introduced the Dreadnought acoustic**

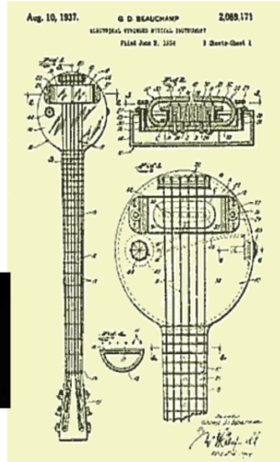
1936 Metal Body Dobro

4

The Origin of the Electric Guitar

- Electromagnetic Pickup
- developed in 1931 by Beauchamp
- the pickup had a pair of horseshoe magnets end-to-end to create an oval wrapped around the strings

- First Electric Guitar (frying pan)
- developed in 1932 by Beauchamp
- the company later became Rickenbacker



5

- 1929 Les Paul
- he first tried to amplify the guitar by jamming a phonograph pickup into the guitar, sliding a telephone mouthpiece under the strings, and then wiring it to a radio producing crude amplification
- developed the first crude solid body electric guitar nicknamed "TheLog"

- 1936 The Gibson ES-150 (E for Electric and S for Spanish)
- developed a bar pickup with 2 long magnets
- 1939 jazz musician Charlie Christian uses the ES-150 in Benny Goodman's Band

6

- 1952 Leo Fender
- was the first to successfully mass-produce a solid-body electric guitar called the telecaster

~~D~~ G D G B D

7

- 1952 Gibson's Ted McCarty introduced an electric guitar endorsed by Les Paul
- the Goldtop had a maple cap on a solid mahogany body.
- had single coil P-90 pickups

- 1954 Fender introduced the Stratocaster
- each pickup has its own character and could be combined in various ways to create numerous effects.

- Late 50's
- Ted McCarty released the Flying V and Explorer a response to the Stratocaster's futuristic design.

8

- 1958 Gibson Les Paul Standard introduced
- had a sunburst finish and newly perfected double-coil, or humbucking PAF pickups

9

- **Q**: When guitarists first crudely electrified their instruments in the 1920's what were they were trying to do?
- **A**: increase their volume so that they could be heard
- **Q**: Why change an instrument that had been successful for hundreds of years?
- **A**: The current design was no longer servicing the needs of musicians, changes had to be mad to increase volume.

10

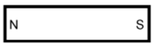
- The solution to increasing the guitar's volume was the electromagnetic pickup.
- The pickup uses electromagnetism and this is what we will now be studying.
- You will learn the physics behind how a pickup works.
- You will make your own pickup.
- You will build your own electric guitar.

11

Appendix O: Iron Filings Lab

Contextual Teaching Lesson 1: Iron Filings Activity

1. Place this paper on top of the magnet(s) and align the poles as indicated.
Sprinkle iron filings onto the paper.
On the recording sheet draw the magnetic field lines you observe.



Contextual Teaching Lesson 1: Iron Filings Activity

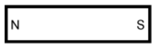
2. Place this paper on top of the magnet(s) and align the poles as indicated.
Sprinkle iron filings onto the paper.
On the recording sheet draw the magnetic field lines you observe.

Contextual Teaching Lesson 1: Iron Filings Activity

3. Place this paper on top of the magnet(s) and align the poles as indicated.
Sprinkle iron filings onto the paper.
On the recording sheet draw the magnetic field lines you observe.

Contextual Teaching Lesson 1: Iron Filings Activity

4. Place this paper on top of the magnet(s) and align the poles as indicated.
Arrange a number of compasses around the magnet(s).
Draw the compasses and needle orientations on the recording sheet.

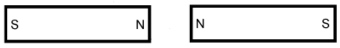


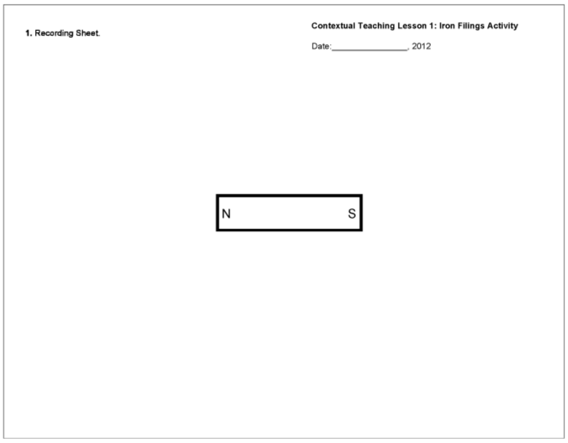
Contextual Teaching Lesson 1: Iron Filings Activity

5. Place this paper on top of the magnet(s) and align the poles as indicated.
Arrange a number of compasses around the magnet(s).
Draw the compasses and needle orientations on the recording sheet.

Contextual Teaching Lesson 1: Iron Filings Activity

6. Place this paper on top of the magnet(s) and align the poles as indicated.
Arrange a number of compasses around the magnet(s).
Draw the compasses and needle orientations on the recording sheet.




1. Recording Sheet.
Contextual Teaching Lesson 1: Iron Filings Activity
Date:_______________, 2012
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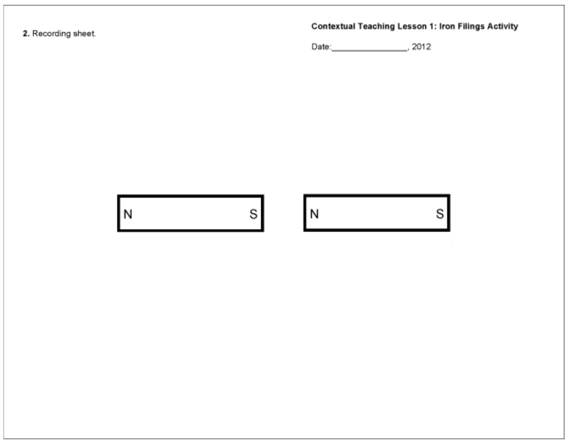
2. Recording sheet.
Contextual Teaching Lesson 1: Iron Filings Activity
Date:_______________, 2012
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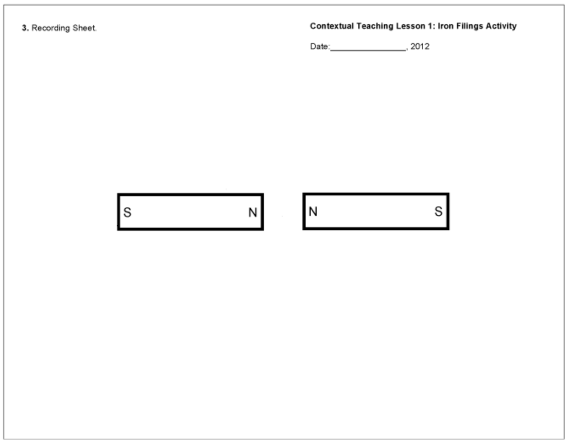
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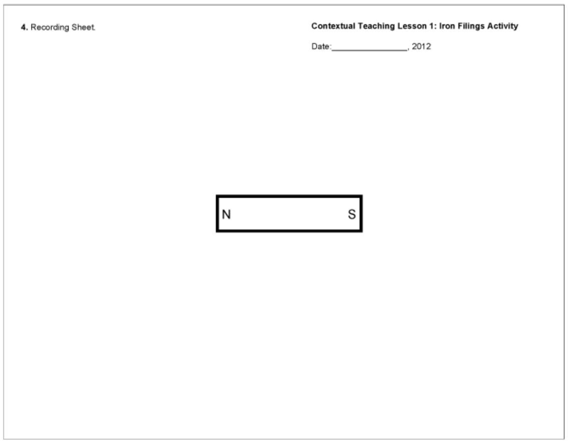
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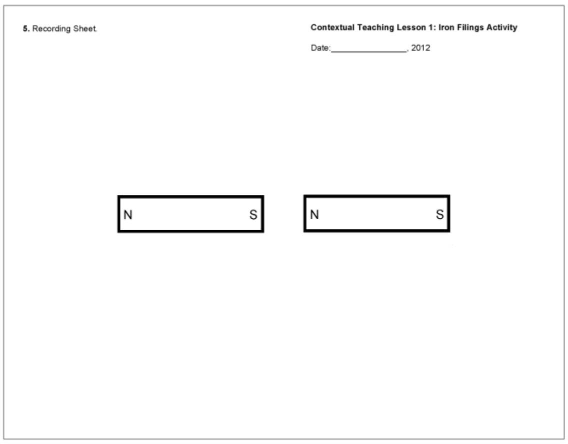
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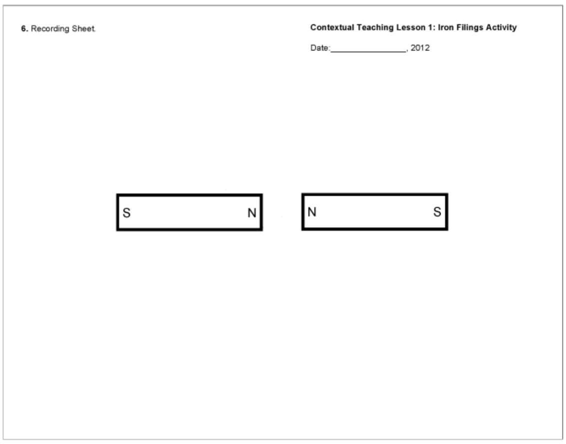
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Appendix P: Magnetism

MAGNETISM

Ancient Greeks (near the City of Magnesia) and Chinese realized certain strange stones attracted iron.

Around 1600, William Gilbert proposed that the Earth itself is A gigantic magnet.

For a long time, people knew only one source of magnetism from Iron. In 1821, a Danish physicist, Oersted noticed that an electrical wire carrying current made a compass orientate. This was the first clue that electricity and magnetism were related to each other.

Ampere, Faraday established the nature of electricity and magnetism (all from their experimental observations).

An unmagnetized piece of iron can be magnetized by stroking it with a magnet somewhat like stroking an object to charge an object.

Magnetism can be induced. If a piece of iron is placed near a strong permanent magnet, it will become magnetized.

1

Magnets

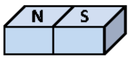
Poles of a magnet are the ends where objects are most strongly attracted and the two poles are called the north pole and south pole.

Like poles repel each other and unlike poles attract each other which is similar to electric charges.

Magnetic poles cannot be isolate. If a permanent magnet is cut in half repeatedly, you will still have a north and a south pole. There is some theoretical basis for monopoles but none have been detected.

2

Magnets exist in pairs of N-S poles.



A theoretical prediction says that it is possible to have magnetic mono-poles but they have not been observed.

3

Magnetic Fields

A vector quantity

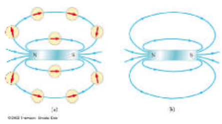
Symbolized by **B**

Direction is given by the direction a *north pole* of a compass needle points in that location
(field lines go from N to S)

Magnetic field lines can be used to show how the field lines, as traced out by a compass, would look

4

Sketching Magnetic Field Lines



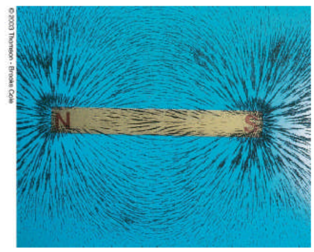
A compass can be used to show the direction of the magnetic field lines

A sketch of the magnetic field lines

The field goes from North to South

5

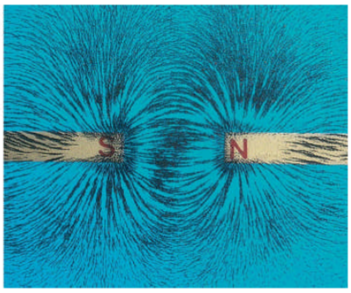
Bar Magnet



Iron filings are used to show the pattern of the magnetic field lines.

6

Unlike Poles



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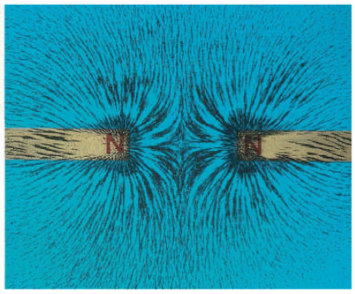
Like Poles



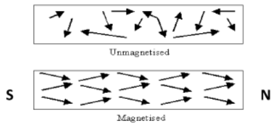
8

Domain Theory

Microscopic examination reveals that a magnet is actually made up of tiny regions known as “domains”.

The domains are about 1mm in size and behave like a tiny magnet with a north and a south pole.

The domain theory is a simple model of magnetism, which states that all materials are made up of tiny regions called domains.



The domains behave like magnets. When they are distributed randomly their magnetic effects cancel, and when the domains become aligned the material is magnetized.

9

Magnetic Fields

In a magnetic field, a current carrying wire experiences a magnetic force.

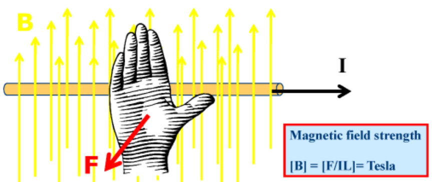
This force has a maximum value when the wire is perpendicularly to the magnetic field lines.

This force is zero when the wire is along the field lines.

The symbol for the magnetic field is **B** and it has the units of the Tesla (T).

10

The right hand rule:
-fingers point in the direction of the magnetic field,
-thumb points in the direction of conventional current
-force comes out of the palm



$$F_{perp} = ILB$$

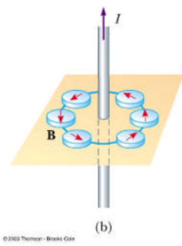
11

Magnetic Fields
Long Straight Wire

A current-carrying wire produces a magnetic field.

The compass needle deflects in directions tangent to the circle.

The compass needle points in the direction of the magnetic field produced by the current.



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Summary of Different Types of Fields

$g = \frac{F}{m}$ Gravitational field=force/mass [m/s^2]

$E = \frac{F}{q}$ Electric field=force/charge [N/c]

$B = \frac{F}{IL}$ Magnetic field=force/current element [T]

13

There are 3 concepts to understand

Motion or force **Magnetic field** **Electricity or current**

Demo 1
Magnet +motion=electricity
A magnet pushed in and out of a coil produces electricity.

Demo 2
Electricity + magnet=motion
An aluminum wire between the poles of a magnet gives a deflection. The deflection is a force or motion.
F=BIL
ex.)speaker

Demo 3
A current carrying wire produces a magnetic filed in loops around the wire.

14

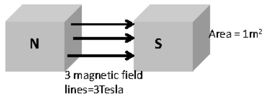
Appendix Q: Magnetic Flux

Magnetic Flux

Φ

1

Consider the ends a horseshoe magnet that produces a magnetic field strength of 3Tesla and assume the area between the poles of the magnet is exactly $1m^2$. If you assume that the area of each end of the magnet is $1m^2$, you can draw this magnet with 3 magnetic lines of force between the poles as follows:



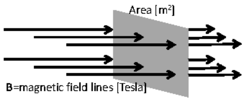
You can see that the number of magnetic lines of force is proportional to the strength of the magnetic field.

We define a new quantity called the magnetic flux Φ that is equal to the number of magnetic lines of force per unit area. In this example there are 3 magnetic lines of force per unit area.

Magnetic flux is commonly visualized as magnetic lines of force passing through a given area.

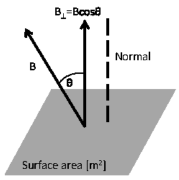
2

Magnetic flux, Φ, represents a quantity of magnetic force lines passing through a given area. The number of magnetic force lines increases if we have a stronger field or if the area enclosed is larger.



Therefore, $\Phi = B_{\perp}A$ (**B** perpendicular to A)
In SI units:
Φ is measured in webers (Wb)
B is measured in Tesla
A is measured in metres squared.

It is important to note that only the component of the magnetic field perpendicular to the area is used in the calculation.
Thus, in general, $\Phi = BA\cos\theta$ **where θ is the** angle between the magnetic field and the normal to the area.



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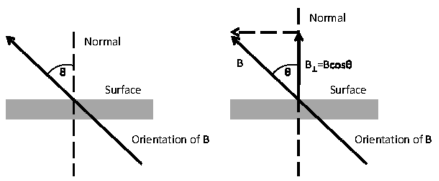
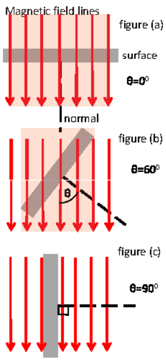


You can see in the figure on the right that the component of **B** that contributes to the magnetic flux is the component that is perpendicular to the surface.

4



In figure (a) the magnetic field lines(red) are perpendicular to the surface area and therefore form no angle with the normal to the surface. The flux is a maximum since $\cos0^0=1$. All the magnetic field lines penetrate the surface and are represented by the red shaded region. $\Phi_{max} = BA\cos0^0 = BA$ [Weber]

In figure (b) the magnetic field lines form an angle of 60^0 to the normal and the flux is less than in diagram (a) since $\cos60^0=0.5$. Less magnetic field lines penetrate the surface and the red shaded region is less than the shading in figure (a). $\Phi = BA\cos60^0 = BA(0.5)$ [Weber]

In figure (c) the magnetic field lines are parallel to the surface area and therefore form 90^0 with the normal to the coil. The flux is a minimum since $\cos90^0=0$. No magnetic filed lines penetrate the surface and there is no shaded region. $\Phi_{min} = BA\cos90^0 = 0$ [Weber]

5

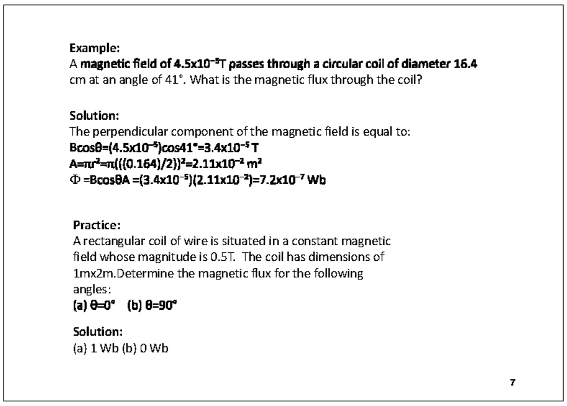
Magnetic Flux
Magnetic Flux is equal to the number of lines of magnetic force per unit area.
Magnetic flux is calculated as the product of the magnetic field strength, the area and the cosine of the angle between the direction of the magnetic field and the normal to the area.

$$\Phi = BA\cos\theta$$

Quantity	Symbol	Unit
Magnetic Flux	Φ	Weber (Wb)
Magnetic field strength	B	Tesla (T)
Area	A	Square metres (m^2)
Angle between the directions of magnetic field and the normal to the surface	θ	

Magnetic flux is a scalar quantity with units of Tm^2 which is called the weber (Wb)

6


Example:
A magnetic field of $4.5x10^{-5}$T passes through a circular coil of diameter 16.4 cm at an angle of 41°. What is the magnetic flux through the coil?
Solution:
The perpendicular component of the magnetic field is equal to:
$B\cos\theta=(4.5x10^{-5})\cos 41°=3.4x10^{-5}$ T
$A=\pi r^2=\pi(((0.164)/2))^2=2.11x10^{-2}$ m^2
Φ =$B\cos\theta A$ =$(3.4x10^{-5})(2.11x10^{-2})=7.2x10^{-7}$ Wb
Practice:
A rectangular coil of wire is situated in a constant magnetic field whose magnitude is 0.5T. The coil has dimensions of 1mx2m.Determine the magnetic flux for the following angles:
(a) θ=0° (b) θ=90°
Solution:
(a) 1 Wb (b) 0 Wb
7

Appendix R: Induced EMF

Induced EMF (electromotive force) and Induced Current

1

There are a number of ways a magnetic field can be used to generate an electric current. The following diagram illustrates one of them. The drawing shows a bar magnet and a helical coil of wire to which an ammeter is connected.

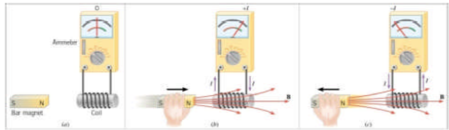


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Figure 22.01 (W0894)

When there is no relative motion between the magnet and the coil, as in figure (a) the ammeter reads zero indicating that no current exists.

When the magnet moves towards the coil as in figure (b) a current I appears. As the magnet approaches, the magnetic field that it creates at the location of the coil becomes stronger and stronger, and it is this changing field that produces the current.

When the magnet moves away from the coil as in figure (c), a current is also produced but with a reversed direction. Now the magnetic field at the coil becomes weaker as the magnet moves away, and once again it is the changing field that generates the current

2

Another way a magnetic field can be used to generate an electric current is if the magnet were held stationary and the coil were moved. Here the magnetic field at the coil would be changing as the coil approached or receded from the magnet.

Only relative motion between the magnet and the coil is needed to generate a current. It does not matter which one moves.

The current in the coil is called an **induced current** because it is brought about (or "induced") by a changing magnetic field. Since an emf is always needed to produce a current, the coil itself behaves as if it were a source of emf. This emf is known as an **induced emf**.

Thus, a changing magnetic field induces and emf in the coil, and the emf leads to an induced current.

3

The following figure shows another way to induce an emf and a current in a coil.

An emf can be induced by **changing the area** of a coil in a constant magnetic field. Here the shape of the coil is being distorted so as to reduce the area. As long as the area is changing, an induced emf and current exist. They vanish when the area is no longer changing.

If the distorted coil is returned to its original shape, thereby increasing the area, an oppositely directed current is generated while the area is changing.

Changing a magnetic field and changing the area of a coil are methods that can be used to create an induced emf. The phenomenon of producing an induced emf with the aid of a magnetic field is called **electromagnetic induction**

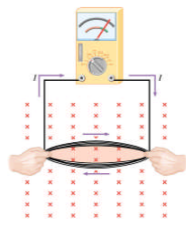

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Figure 22.03 (W0896)

4

Appendix S: Faraday's Law of Electromagnetic Induction

Faraday's Law of Electromagnetic Induction

1

Faraday discovered that there must be a changing magnetic field in a loop of wire before an emf will be induced in the loop.

Another way to state this is that there must be a change in flux through the loop of wire.

In this context, the word "change" refers to the passage of time.

A flux that is constant in time does not create an emf.

Faraday's law of electromagnetic induction brings together the idea of magnetic flux and the time interval during which it changes.

In fact, Farady found that the magnitude of the induced emf is equal to the time rate of change of magnetic flux.

$$\xi = -\frac{\Delta\Phi}{\Delta t}$$

Often, the magnetic flux passes through a coil of wire containing more than one loop (or turn). If the coil consists of N loops, and if the same flux passes through each loop, it is found experimentally that the total emf is N times that indicated in a single loop.

2

For the general case of N loops, Faraday's law of electromagnetic induction describes the total emf in the following way where the average emf induced in a coil of N loops is:

$$\xi = -N\left(\frac{\Phi - \Phi_0}{t - t_0}\right) = -N\left(\frac{\Delta\Phi}{\Delta t}\right)$$

$\Delta\Phi$	= the change in the magnetic flux through one loop
Δt	= the time interval during which the change occurs
$\Delta\Phi/\Delta t$	= the average time rate of change of the flux that passes through one loop
$N(\Delta\Phi/\Delta t)$	= the average time rate of change of the flux that passes through N loops of the coil

3

Faraday's Law of Electromagnetic Induction

Faraday's law states that the emf induced in a circuit containing a coil of N loops is N times the time rate of change of magnetic flux for the circuit. The magnitude of the induced emf is calculated by the negative of the number of loops times the change in magnetic flux divided by the change in time.

$$\xi = -N\left(\frac{\Phi - \Phi_0}{t - t_0}\right) = -N\left(\frac{\Delta\Phi}{\Delta t}\right)$$

Quantity	Symbol	Unit
Induced emf	ξ	Volt (V)
Number of loops	N	
Initial magnetic flux	Φ_0	Weber(Wb)
Final magnetic flux	Φ	Weber(Wb)
Change in magnetic flux in one loop	$\Delta\Phi$	Weber(Wb)
Initial time	t_0	Seconds(s)
Final time	t	Seconds(s)
Time interaval	Δt	Seconds(s)

Note: The minus sign is there to remind us in which direction the induced emf acts. A current produced by an induced emf moves in a direction so that its magnetic field opposes the original change in flux.

4

Faraday's law states that an emf is generated if the flux changes for **any** reason.

Φ=**BA**cosθ [Webers]

The flux depends on 3 factors, any of which may change.

B=magnetic field [Teslas]

A=area [m^2]

θ= angle [degrees]

If **B** changes, then the magnetic flux change is $\Delta\Phi=\Delta BA\cos\theta$

If **A** changes, then the magnetic flux change is $\Delta\Phi=B\Delta A\cos\theta$

If θ changes, then the magnetic flux change is $\Delta\Phi=\Delta BA\Delta\cos\theta=BA(\cos\theta-\cos\theta_0)$

In calculating the induced emf, you can use the **rate of change of the area** or the **rate of change of the magnetic field** or the **rate of change of the angle.**

5

Faraday's Law $\quad \xi = -N\left(\frac{\Delta\Phi}{\Delta t}\right) = -\frac{NBA\cos\theta}{\Delta t}$

If you use:	Then Faraday's Law can be written as:
$\left(\frac{\Delta A}{\Delta t}\right)$	$\xi = -NB\left(\frac{\Delta A}{\Delta t}\right)\cos\theta$
$\left(\frac{\Delta B}{\Delta t}\right)$	$\xi = -N\left(\frac{\Delta B}{\Delta t}\right)A\cos\theta$
$\left(\frac{\Delta\cos\theta}{\Delta t}\right)$	$\xi = -NBA\left(\frac{\Delta\cos\theta}{\Delta t}\right)$

6

3 Practice Problems

Example 1: Induced EMF from a Changing Magnetic Field
A coil consists of 20 turns (loops) of wire. Each loop of wire has an area of $0.400m^2$. At one moment, the magnetic field threading these loops is 0.250T and 0.480s later the magnetic field has dropped to 0.100T. What is the induced emf if the magnetic field direction remains perpendicular to the area of the loops?

Example 2: Induced EMF from a Changing Angle
A coil of 25 loops is initially placed so that the angle the normal to the coil makes with the magnetic field direction is 90^0. The coils have an area of $0.600m^2$ and the magnetic field is 0.0850T. IF it takes 0.0355s to rotate the coil 40^0, what is the induced emf?

Example 3: The Rate of Change of Area and the Induced EMF
A rod slides along two conducting rails connected to a light bulb. The rod sweeps out an area at a rate of $0.625m^2/s$ in the plane of the rails. A magnetic field of 0.800T points in a direction so that it is perpendicular to the plane. What is the emf induced in the circuit?

7

Solutions

8

Example 1: Induced EMF from a Changing Magnetic Field
A coil consists of 20 turns (loops) of wire. Each loop of wire has an area of $0.400m^2$. At one moment, the magnetic field threading these loops is 0.250T and 0.480s later the magnetic field has dropped to 0.100T. What is the induced emf if the magnetic field direction remains perpendicular to the area of the loops?

Given:
Number of loops in the coil N=20
Area of one loop $\mathbf{A}=0.400m^2$
Initial magnetic field $\mathbf{B}_0=0.250T$
Final magnetic field $\mathbf{B}=0.100T$
Time interval $\Delta t=0.480s$
Angle between magnetic field and normal $\theta=0^0$
Unknown:
Induced emf $\xi=?$
Equation:
Find the flux change using $\Delta\Phi=\Delta\mathbf{B}\mathbf{A}\cos\theta$

Then find the induced emf using $\xi=-N\left(\frac{\Delta\Phi}{\Delta t}\right)$

Substitute and solve:
$\Delta\Phi=\Delta\mathbf{B}\mathbf{A}\cos\theta$
$\Delta\Phi=(0.100-0.250)(.400)\cos 0^0$
$\Delta\Phi=-0.0600Wb$

$$\xi=-N\left(\frac{\Delta\Phi}{\Delta t}\right)$$

$=-(20)(-0.0600)/(0.480)$
$=2.50V$

The induced emf is 2.50V

9

Example 2: Induced EMF from a Changing Angle
A coil of 25 loops is initially placed so that the angle the normal to the coil makes with the magnetic field direction is 90^0. The coils have an area of $0.600m^2$ and the magnetic field is 0.0850T. IF it takes 0.0355s to rotate the coil 40^0, what is the induced emf?

This is the case where the angle of orientation of the magnetic field and the normal to the area changes.

Given:
Number of loops in the coil N=25
Area of one loop $\mathbf{A}=0.600m^2$
Magnetic field $\mathbf{B}=0.0850T$
Time interval $\Delta t=0.03550s$
Initial angle between magnetic field and normal $\theta_0=90^0$
Final angle between magnetic field and normal $\theta=40^0$
Unknown:
Induced emf $\xi=?$
Equation:
Find the flux change using $\Delta\Phi=\mathbf{B}\mathbf{A}\Delta\cos\theta$

Then find the induced emf using $\xi=-N\left(\frac{\Delta\Phi}{\Delta t}\right)$

Substitute and solve:
$\Delta\Phi=\mathbf{B}\mathbf{A}\Delta\cos\theta$
$\Delta\Phi=\mathbf{B}\mathbf{A}(\cos\theta-\cos\theta_0)$
$\Delta\Phi=(0.0850(0.600)(\cos 40^0-\cos 90^0)$
$\Delta\Phi=(0.0850(0.600)(0.766-0)$
$\Delta\Phi=0.0391Wb$

$$\xi=-N\left(\frac{\Delta\Phi}{\Delta t}\right)$$

$=-(25)(0.0391)/(0.0355)$
$=-27.5V$

The induced emf is -27.5V

10

Example 3: The Rate of Change of Area and the Induced EMF
A rod slides along two conducting rails connected to a light bulb. The rod sweeps out an area at a rate of $0.625m^2/s$ in the plane of the rails. A magnetic field of 0.800T points in a direction so that it is perpendicular to the plane. What is the emf induced in the circuit?

Given:
Number of loops in the coil N=1
Rate of change of area of one loop $\Delta\mathbf{A}/\Delta t=0.625m^2/s$
Magnetic field $\mathbf{B}=0.800T$
Angle between magnetic field and normal $\theta=0^0$
Unknown:
Induced emf $\xi=?$
Equation:
Since the rate of change of area is given, use

$$\xi=-NB\left(\frac{\Delta A}{\Delta t}\right)\cos\theta$$

Substitute and solve:

$=-(1)(0.800)(0.625/1)\cos 0^0$
$=-0.500V$

The induced emf is -0.500V

11

Appendix T: Lenz's Law

Lenz's Law

1

An induced emf drives current around a circuit just as the emf of a battery does. With the battery, conventional current is directed out of the positive terminal, through the attached device and into the negative terminal. The same is true for an induced emf, although the location of the positive and negative terminals is generally not as obvious.

Lenz's Law is a method for determining the polarity or algebraic sign of the induced emf, so the terminals can be identified.

The net magnetic field penetrating a coil of wire results from 2 contributions. One is the original magnetic field that produces the changing flux that leads to the induced emf. The other arises because of the induced current, which, like any current, creates its own magnetic field. The field created by the induced current is called the ***induced magnetic field***.

To determine the polarity of the induced emf, we will use a method based on a discovery made by the Russian physicist Heinrich Lenz (1804-1865). This discovery is known as ***Lenz's Law.***

Lenz's Law
The induced emf resulting from a changing magnetic flux has a polarity that leads to an induced current whose direction is such that the induced magnetic field **opposes** the original flux change.

2

Recall the following:

Figure (a)
A long, straight, current-carrying wire produces magnetic field lines that are circular about the wire

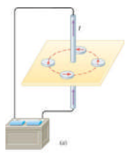

Figure (b)
Right Hand Rule
Curl the fingers of the right hand into the shape of a half-circle. Point the thumb in the direction of the conventional current I, and the tips of the fingers will point in the direction of the magnetic field B

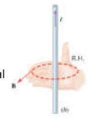

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Figure 21.25 (W0845)

3

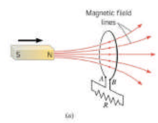
In the diagram, as the magnet moves to the right, the magnetic flux through the loop increases.

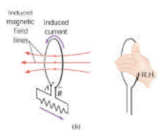
To oppose the rightward increase in the flux, the direction of the induced magnetic field must be opposite or leftward to the field of the bar magnet.

Since the field of the bar magnet passes through the loop from left to right in part (a) of the diagram, the induced field must pass through the loop from right to left, as in part (b) in order to oppose it.

To create such an induced field, the induced current must be directed **counterclockwise** around the loop, when viewed from the side nearest the magnet. The north pole of the induced magnetic field must be directed to the left from the right hand rule.

The loop behaves as a source of emf, just like a battery. Since conventional current is directed into the external circuit from the positive terminal, point A in figure (b) must be the positive terminal while point B must be the negative terminal.





Cutnell & Johnson
Wiley Publishing
Physics 5th Ed.
Figure 22.16 (W0899a)

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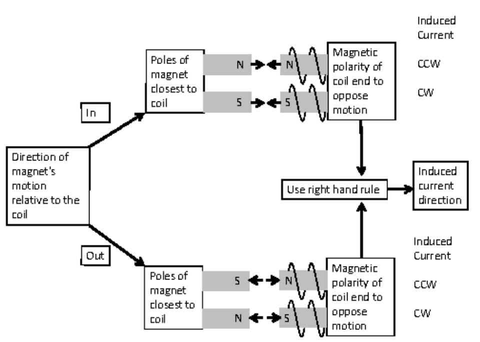

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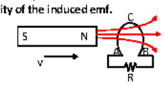
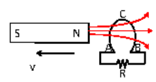
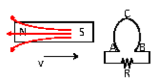
There are 4 possibilities when determining the direction of the induced current and polarity of the induced emf.



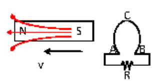
The N pole of a bar magnet is moving towards the coil of wire



The N pole of a bar magnet is moving away from the coil of wire

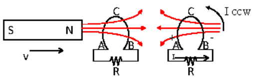


The S pole of a bar magnet is moving towards the coil of wire



The S pole of a bar magnet is moving away from the coil of wire

6



The N pole of a bar magnet is moving towards the coil of wire

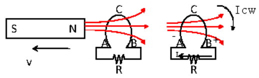
To find the direction of the induced current and the polarity of the induced emf, we could use the following procedure:

1. The first step is to determine if the magnetic flux is increasing or decreasing. In this case, the magnetic flux is increasing since the magnitude of the magnetic field at the loop is increasing as the magnet approaches.

2. Next, we must find the direction of the magnetic field due to the induced current in the wire. This field must oppose the change in flux produced by the original field.
Original flux change: increasing pointing from left to right. An increasing flux means the induced flux change must point in the opposite direction: right to left.

3. Now, we use the right-hand rule to determine the direction of the induced current. Curl the fingers of the right hand in the direction of the induced magnetic field (fingertips at the centre of the loop pointing from right t left). Place the thumb at point C. The thumb then indicates the direction of the induced current. This shoes that when viewed from the side nearest the magnet, the current is **counter-clockwise** in the loop. The loop behaves like a source of emf just like a battery. The conventional current is directed into the external circuit from the positive terminal. The current flows from A to R to B. **A is positive and B is negative.**

7



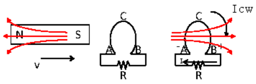
The N pole of a bar magnet is moving away from the coil of wire

1. The magnetic field caused by the magnet is pointing towards the coil (left to right) and is decreasing.

2. Since the original field is decreasing, the induced magnetic flux opposes this change and must increase the flux in the loop. So the magnetic flux due to the induced current must also point from left to right (same direction as the original)

3. Placing your curved hand with your fingertips at the centre of the loop pointing from left to right, and placing your thumb at C, your thumb shows that the induced current is **clockwise** (from C to B to A to C). The induced current flows from B through R to A. So B is positive and A is negative. The current induced in the coil is clockwise when viewed from the magnet.

8



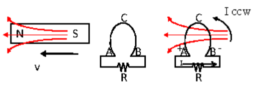
The S pole of a bar magnet is moving towards the coil of wire

1. The magnetic field caused by the magnet is pointing to the left, away from the coil, and is increasing.

2. The induced magnetic field must oppose this change in magnetic flux. The induced magnetic field must point in the opposite direction to the original field-that is, from left to right.

3. Placing your curved right hand with the fingertips at the centre of the loop pointing right, your thumb at c will point down, giving an induced current that is **clockwise** when viewd from the magnet.

9



The S pole of a bar magnet is moving away from the coil of wire

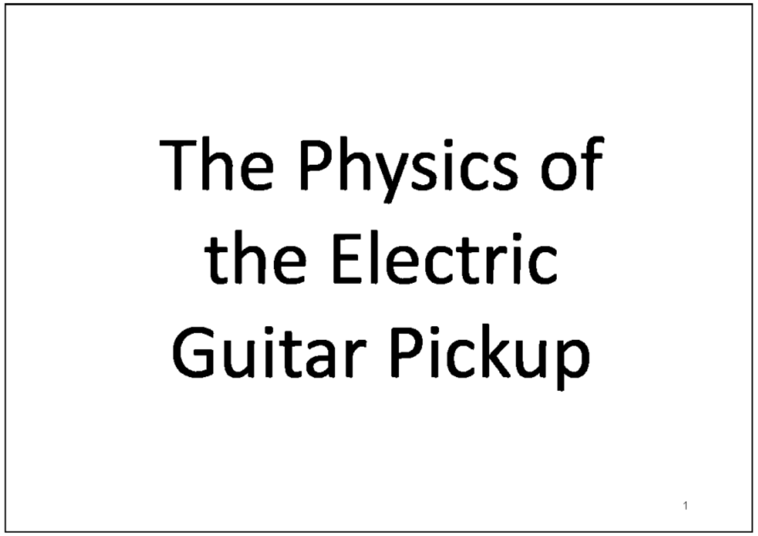
1. The magnetic field caused by the magnet is to the left and is decreasing.

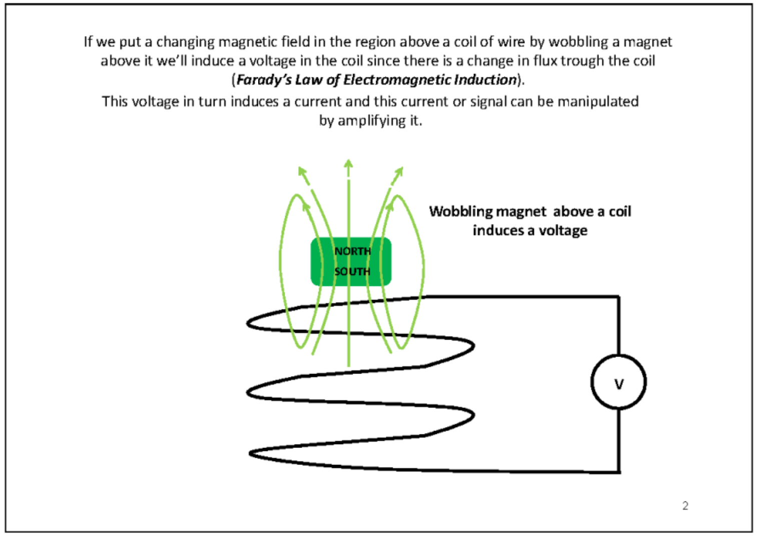
2. The induced magnetic field must oppose this change and increase to the left (same direction as the original field).

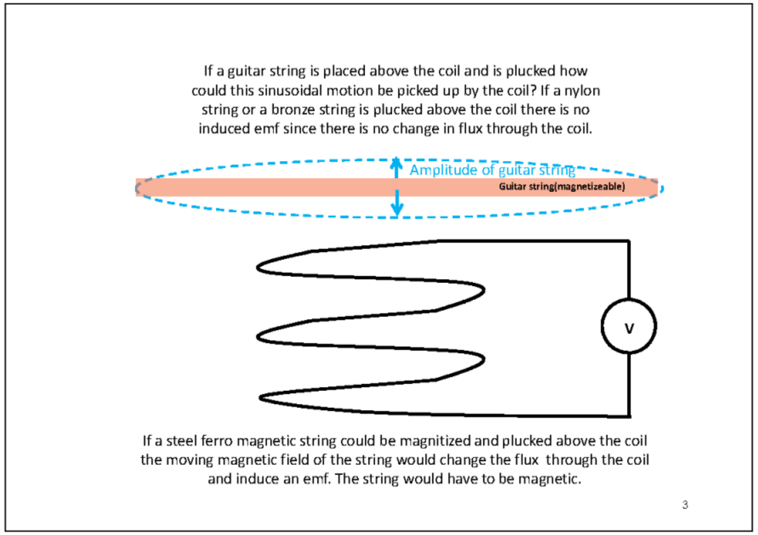
3. Placing your curved right hand with the fingertips at the centre of the loop pointing from right to left, your thumb, when placed at C, will point up. The current induced is **counter-clockwise** when viewed from the magnet.

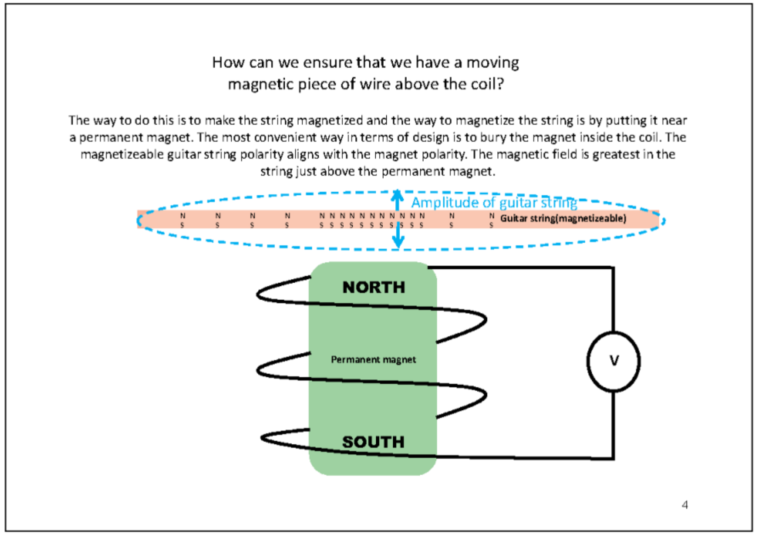
10

Appendix U: The Physics of the Electric Guitar Pickup

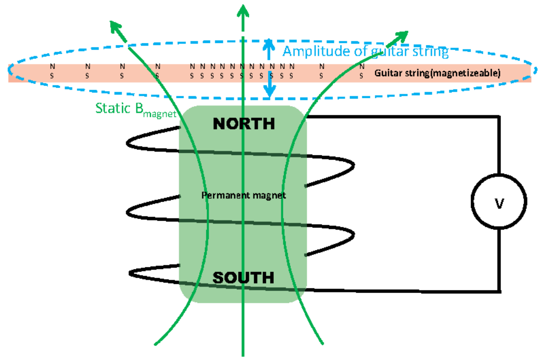

The Physics of the Electric Guitar Pickup
1


If we put a changing magnetic field in the region above a coil of wire by wobbling a magnet above it we'll induce a voltage in the coil since there is a change in flux trough the coil (*Farady's Law of Electromagnetic Induction*).
This voltage in turn induces a current and this current or signal can be manipulated by amplifying it.
NORTH
SOUTH
Wobbling magnet above a coil induces a voltage
V
2


If a guitar string is placed above the coil and is plucked how could this sinusoidal motion be picked up by the coil? If a nylon string or a bronze string is plucked above the coil there is no induced emf since there is no change in flux through the coil.
Amplitude of guitar string
Guitar string(magnetizeable)
V
If a steel ferro magnetic string could be magnitized and plucked above the coil the moving magnetic field of the string would change the flux through the coil and induce an emf. The string would have to be magnetic.
3


How can we ensure that we have a moving magnetic piece of wire above the coil?
The way to do this is to make the string magnetized and the way to magnetize the string is by putting it near a permanent magnet. The most convenient way in terms of design is to bury the magnet inside the coil. The magnetizeable guitar string polarity aligns with the magnet polarity. The magnetic field is greatest in the string just above the permanent magnet.
Amplitude of guitar string
Guitar string(magnetizeable)
NORTH
Permanent magnet
SOUTH
V
4

There are two magnetic fields at play here.
The first is the static magnetic field generated by the stationary bar magnet.



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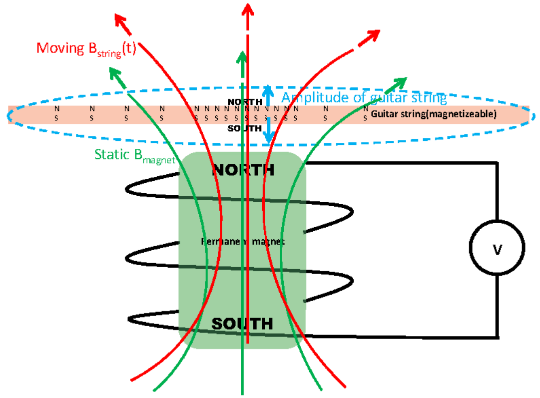
The second magnetic field is the field in the guitar string just above the stationary magnet. The stationary magnet has magnetized the string and the string's magnetic field is in the same direction as the stationary bar magnet. When the string is plucked the magnetic field of the string changes with respect to time.



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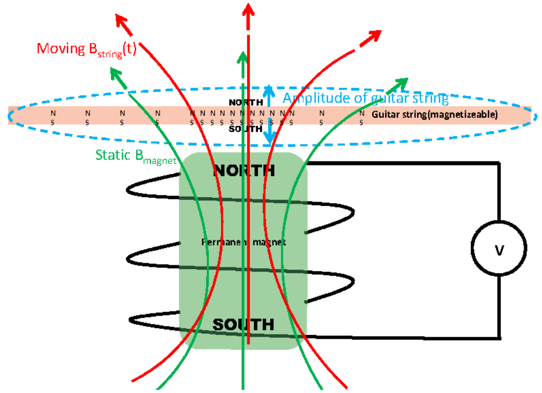
The magnetic field of the guitar string is weak compared to the magnetic field of the permanent magnet but that doesn't matter since all that is needed to induce an emf in the coil is to change the total flux through the coil. The guitar string's magnetic field wraps around and cuts through the coil and because the string is moving it is contributing a changing flux in the coil.



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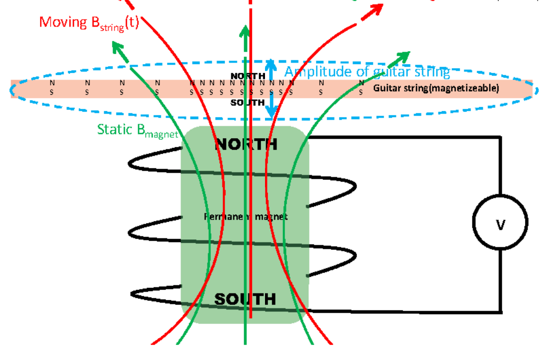
One contribution to the total flux is the static magnetic field of the permanent magnet(green lines) the other is the moving magnetic field of the guitar string(red lines). B_{magnet} does not change over time but $B_{string}(t)=B_{string}\sin(\omega t)$ is a function of time. The total net flux is the sum of $B_{magnet}+B_{string}(t)$ multiplied by the area(A) of the coil and the number of turns(N) of coils.

$$\Phi_{net}=(B_{magnet}+B_{string}(t))A_{loop}N_{loop}$$



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Since the total flux in the coil is changing with respect to time there is an induced electromotive force and an induced current. The current is the signal that can be amplified.

Faraday's Law of Electromagnetic Induction States:
The average EMF (electromotive force) induced in a coil of N loops is:

$$EMF = \xi = Voltage = -N\left(\frac{\Delta\Phi}{\Delta t}\right)$$

Δt is the change in magnetic flux through one loop and

$\Delta\Phi$ is the time interval during which the change occurs

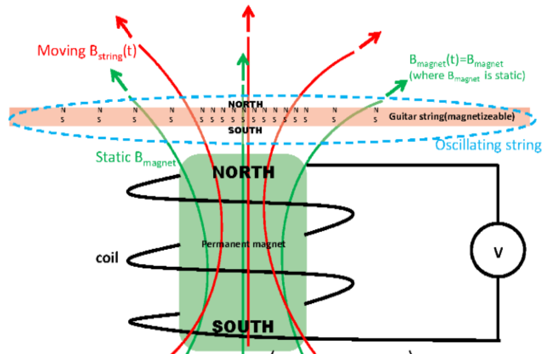
$\frac{\Delta\Phi}{\Delta t}$ is the average time rate of change of flux that passes through one loop

$N\left(\frac{\Delta\Phi}{\Delta t}\right)$ is the average time rate of change of flux that passes trough N loops of the coil

For the guitar pickup

$$EMF = V = -\frac{\Delta\Phi}{\Delta t} = -\frac{\Phi_{net}}{\Delta t} = -\frac{\left(B_{magnet} + B_{string}(t)\right)A_{loop}N_{loop}}{\Delta t}$$

9



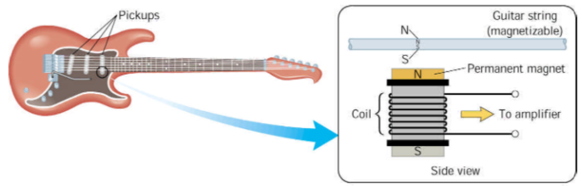
$$EMF = V = -\frac{\Delta\Phi}{\Delta t} = -\frac{\Phi_{net}}{\Delta t} = -\frac{\left(B_{magnet} + B_{string}(t)\right)A_{loop}N_{loop}}{\Delta t}$$

(Bidinosti, C., personal communication, August 05, 2011) 10

How a Guitar Pickup Works

The guitar string is made from a magnetizeable metal. The pickup itself consists of a coil of wire with a permanent magnet located inside the coil. The permanent magnet produces a magnetic field that penetrates the guitar string, causing it to become magnetized with north and south poles. When the magnetized string is plucked, it oscillates above the coil, thereby changing the magnetic flux that passes through the coil. The change in flux induces an emf in the coil. The polarity of the emf reverses with the vibratory motion of the string, so a string vibrating at 440Hz, for example, induces a 440Hz ac emf in the coil. This 440Hz signal, after being amplified, is sent to the speakers, which produces a 440Hz sound wave. (Cutnell and Johnson Wiley Publishing)

11



Cutnell & Johnson
Wiley Publishing
Physics 5th Ed.
Figure 22.18 (W0901)
C M Y K

12

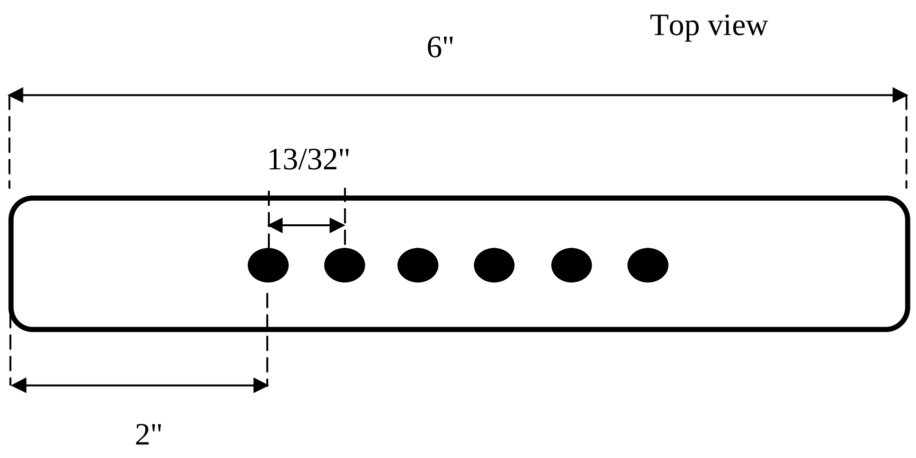
Appendix V: Construction of the Electric Guitar Pickup

Construction of the Guitar Pickup

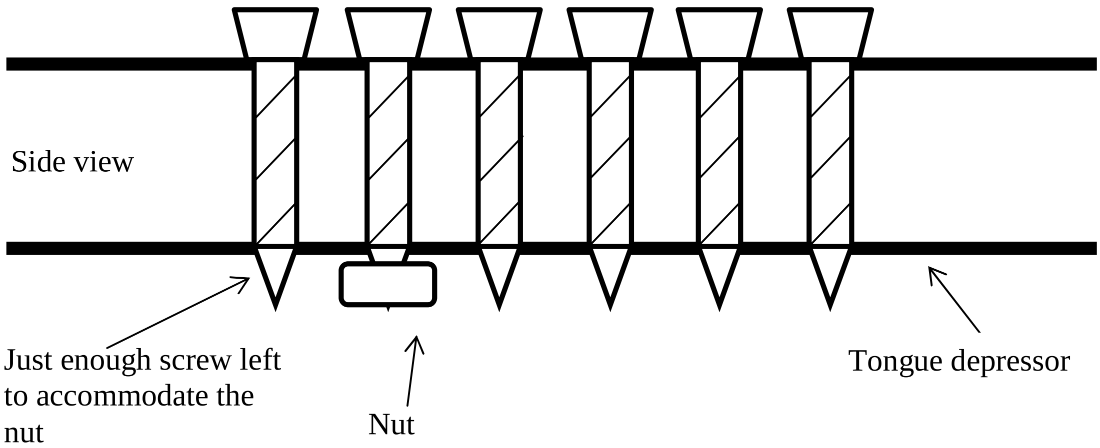
Materials

6"x11/16"x1/16"wooden tongue depressors
six 32x3/4 machine screws
six 32 machine screw nuts
3/32 wood drill bit
Sandpaper
Small wood clamps
Electric drill
28 Mag/Scs-1/4lb magnet wire
12mx0.075mmx12mm Teflon plumbing tape
Jack socket
Soldering iron
Solder
Soldering paste

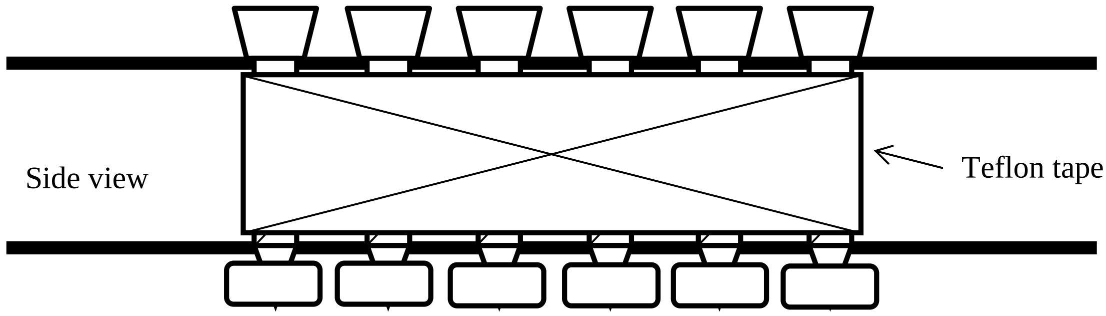
In an electric guitar pickup there are 6 magnets evenly spaced below each guitar string. Rather than using magnets, this construction will use metal screws. The first step is to drill holes into 2 tongue depressors that the screws will sit in. The standard single coil Fender style electric guitar pickup has the centres of each of the magnets spaced every 0.407 inches. This corresponds to a centre spaced every 13/32 inches or every 6.5/16 inches. Since the tongue depressor is 6 inches long, the first centre should be drilled at 2inches from the end of the tongue depressor so that all six holes, spaced every 6.5/16 inches, are evenly spaced in the centre of the tongue depressor. The holes should now be evenly spaced leaving 2 inches of tongue depressor on either side of the first and last holes. The hole centre spacing should be marked on one tongue depressor and then stacked on top of the other tongue depressor and clamped securely. Using an electric drill with a 3/32 inch drill bit, the six holes can be drilled through both clamped tongue depressors. There will be wood splinters coming from the holes and these can be cleaned up by sanding the tongue depressor surfaces.



The 6- ¾ inch screws can now be screwed through one of the tongue depressors and the screws should be screwed entirely through so that the head of each screw is tight to the tongue depressor. The bottom tongue depressor should now be lined up with the bottom of the screws of the top tongue depressor. Each screw should be turned so as to leave just enough screw poking through the bottom tongue depressor so the nuts can be attached to each screw.

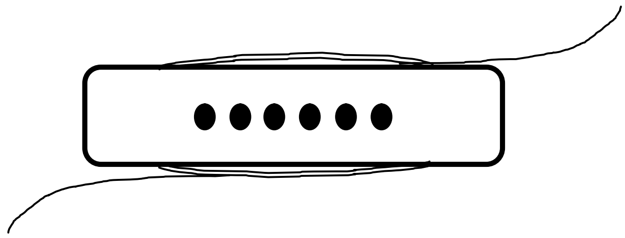


White teflon plumbers tape is now wrapped around the threads of the screws. This will help prevent the threads of the screws from cutting into the magnet wire when it is wrapped around them.



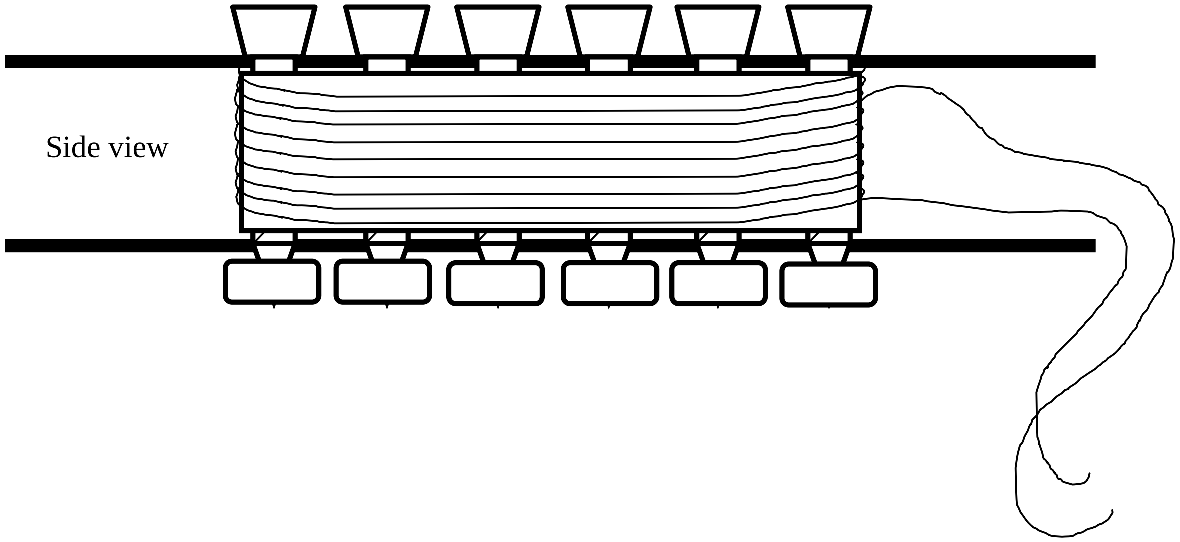
The magnet wire should now be wrapped around the screws until enough wire has been wrapped around to fill the space between the screws and the outside edge of the tongue depressor with wire.

Top view

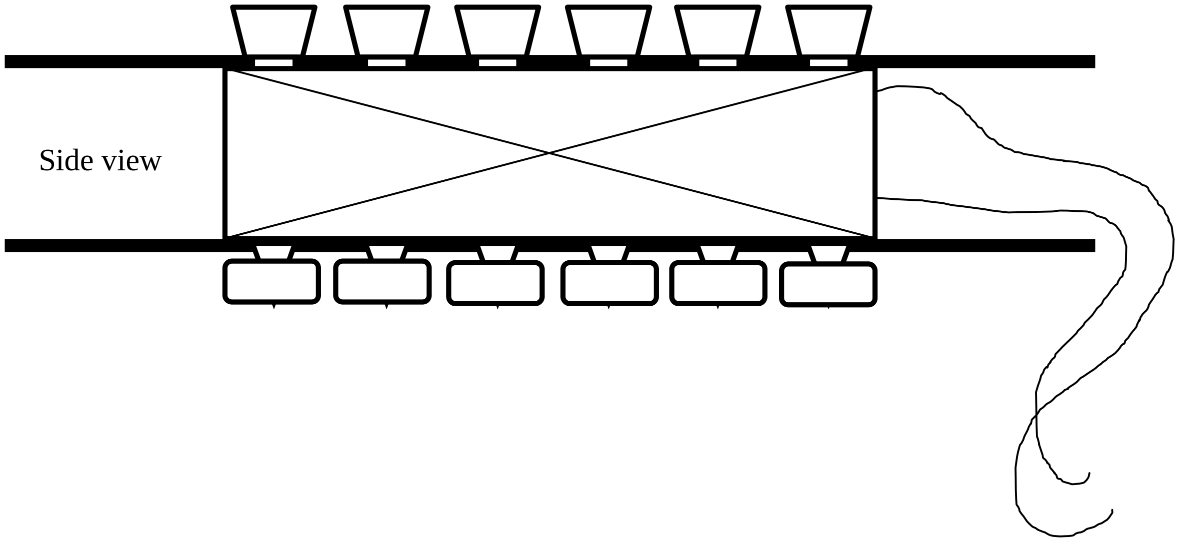


Teflon tape should now be wrapped around the wires to secure the windings

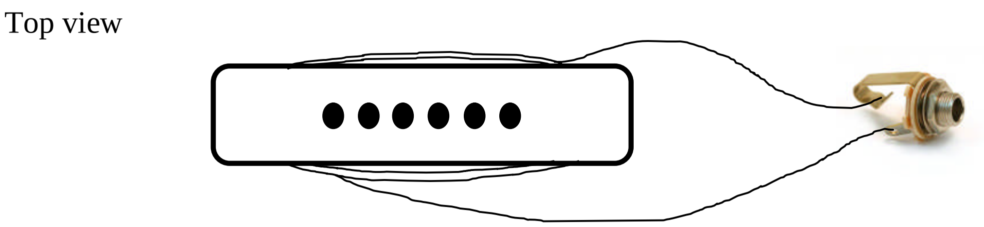
Side view



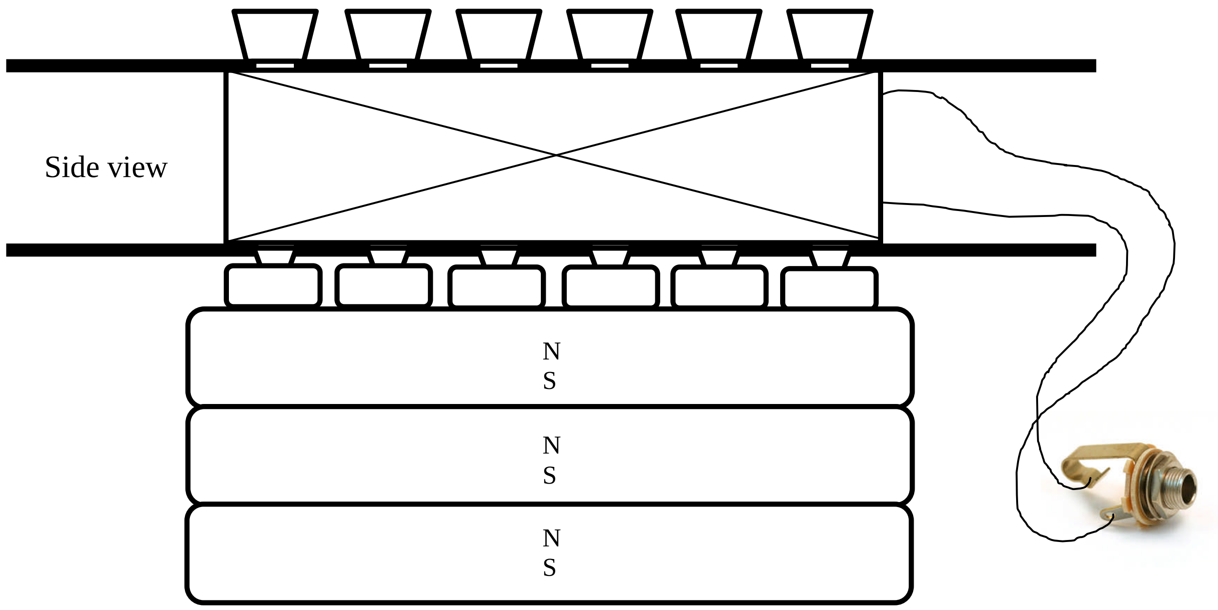
Side view



The wires of the pickup should now be soldered to the jack



A number of ceramic magnets are attached to the nuts of the pickup to complete the construction.



Appendix W: Construction of the Electric Guitar

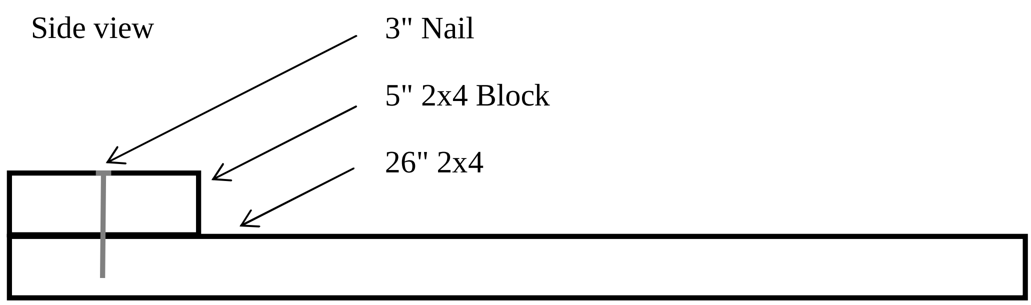
Construction of the Electric Guitar

Materials

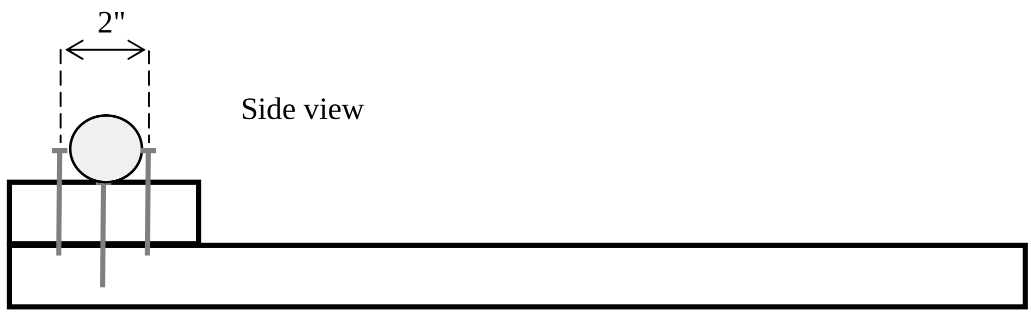
Guitar Body
- 26" length of 2"x4" wood stock
- 5" length of 2x4 wood stock
- four 3" common nails with large head
- 237ml, 7.5" long glass coca-cola bottle
- 0.054 inch/1.37mm gauge nickel steel electric guitar string
- hammer
- screwdriver

Tuning Machine
- 3.5"x1.5"x10/16" wood stock
- 5/16" drill bit
- one 3/8" peg head hole guitar tuning machine
- three 6x2 flat socket head screws

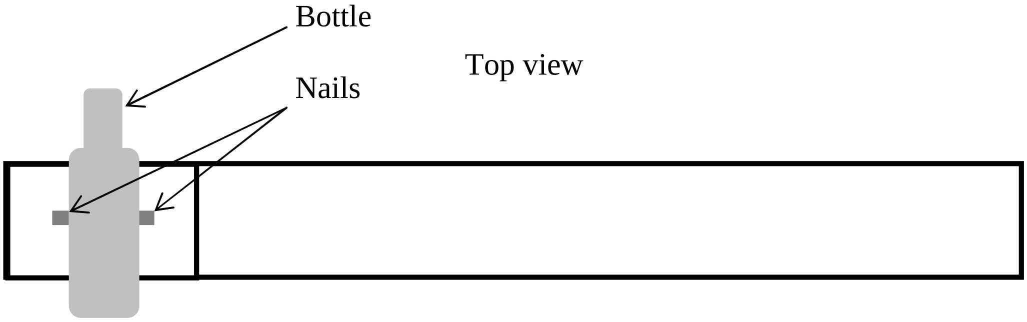
To make the body of the guitar the 5" block is nailed to one of the ends of the 26" piece of 2x4.



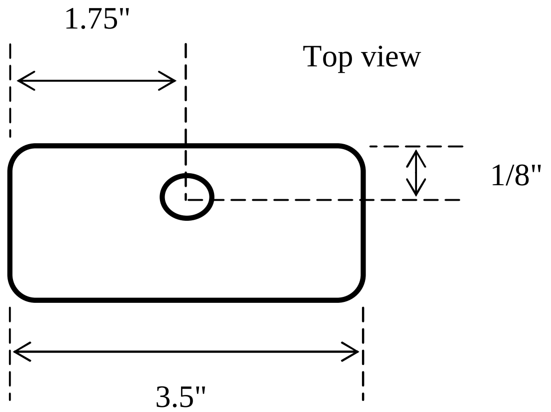
The bottle must now be secured in between two 3" nails on the 5" block. The width of the bottle is 2" so the nails must be spaced so that the bottle may be secured between them. The nails may need to be bent a little in order that the bottle will be secure.



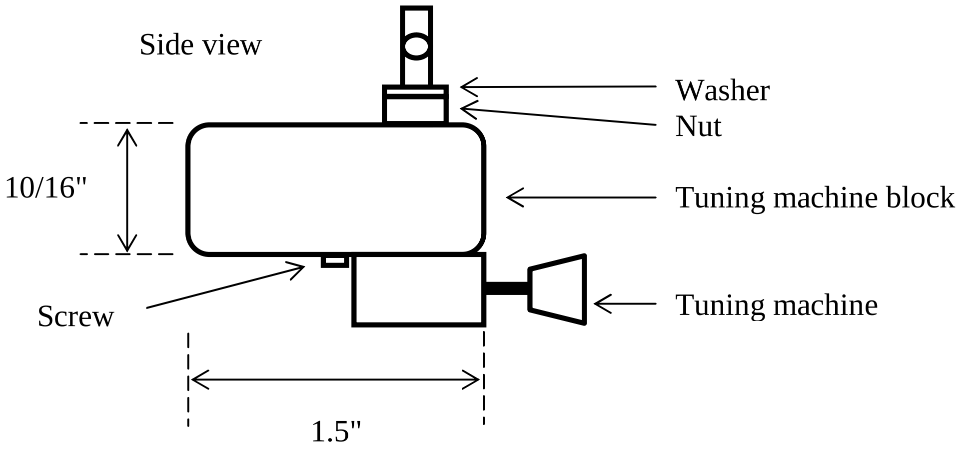
The 7.5" bottle is longer than the width of the block so it should be evenly centered on the block with an even amount of bottle hanging over each edge.



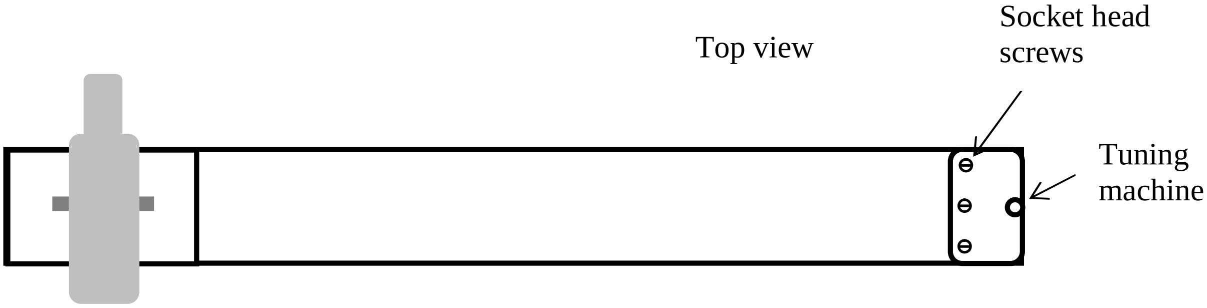
The tuning machine must be attached to the other end of the guitar body using the 3.75"x1.5"x10/16" wood stock. A 5/16" drill bit will be used to drill a hole for the 3/8" guitar tuning machine and the centre of the hole should be drilled 1.75" from one side of the block and 1/8" from the front.



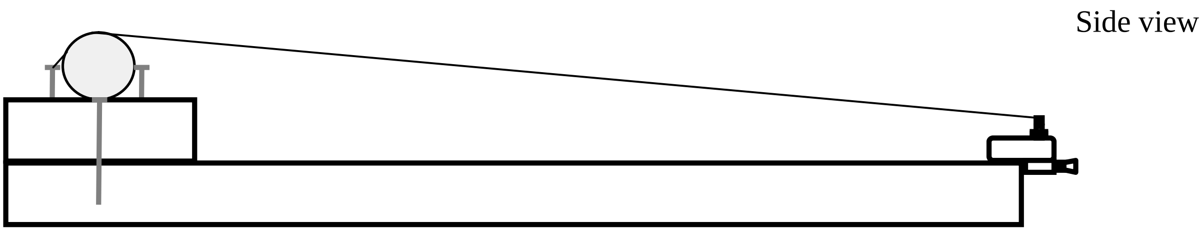
The tuning machine will be fitted into the hole and attached to the bottom of the block by 4 tiny screws included with the tuning machine. The tuning machine came with a nut and washer and these should be attached to the top of the tuning machine.



The tuning machine block is now fastened to the guitar using three 6x2 flat socket head screws.



The guitar string must now be attached to the guitar. The end of the string has a small brass ball with a small hole in it. The string is fed through this brass ball forming a knot that can be attached to the left nail holding the bottle. The other free end of the string is now fed into the tuning machine and turned to apply tension.



The electric guitar pickup is now placed under the string and can be attached with masking tape.