Matt Angiono
Phys 4810

The Tutorial Supplement Method of Teaching Introductory Physics

At the center of the discussion about physics education research, there has always been the most crucial and yet still disputed question of how to teach introductory physics. For the past few centuries, the common method of teaching has been for instructors to lecture to their students, and grades were mostly determined from scores on homework, exams or the combination of both. However, this method has proven to be unsuccessful on the large scale, and studies have shown that the lecturing method is simply not an effective way for students to learn (McDermott 1993). Since this realization, the field of physics education research has grown immensely, and many new methods for teaching physics have arisen. One technique that has been somewhat more successful in recent years is the tutorial method (McDermott 2002). This is where students are guided through an introductory course by tutorials, which give students the tools and basic guidance necessary to figure out the physics for themselves.

Tutorials are books that present questions and suggest ideas that coincide with each topic, and they force students to come up with their own solutions. The role of the instructors in the tutorial atmosphere is not to lecture or "teach" at all, but rather to ask constructive questions that will lead students in the right direction. In this method, a student with a question is almost always confronted with a more basic question in return, one that will generally lead them to the answer. If this doesn't work, the instructor then proposes an even more basic question. The difficulty with this method is that it is very time consuming, requiring multiple instructors for each section (even in smaller ones) and a lot of individual attention from them. This makes it difficult to cover as much material as a strictly lecture-based course, which is possibly a large reason this method hasn't been as widely accepted. We've seen similar problems to this in trying to design full-size laboratory classes. Resources can be a huge limiting factor in large universities where introductory class sizes are often in the range of 400 or 500 students. The solution to this problem has been to create a mix between the lecture and tutorial methods, as has been done with laboratory classes for many years. The regular three hours a week are taught as a lecture course, but then an additional hour is set aside for students to meet in a tutorial section, which supplements the material they learn in lecture and allows them some exposure to physical examples.

The tutorial supplement is the method we have applied here at CU Boulder, and it seems to have been fairly successful. Studies have been done at the University of Washington where the Tutorials were first developed to show that the tutorials are a much better substitute to the recitations where teaching assistants would just go over homework problems (McDermott 2002). Throughout this past semester, I have worked in tutorials as an LA (learning assistant), in which I am one of the “guides” that helps students through the tutorials. The goal of the tutorial supplement method is the same as in workshop physics, in that we are not to give students answers, but rather to give them the direction they need to find the answers for themselves. The purpose of my project is to explain and analyze my experience over the past semester and to show where I feel the most significant improvements need to be made. I will explain in detail why these are important and how they will benefit the students, and then provide an example tutorial that demonstrates the changes that I have made. It will also include information that I would provide in an instructor’s edition, where the purpose of each problem is stated so that they know what to be expecting from students.

The first thing that I would like to discuss is the overall structure of the tutorial sessions themselves. It is important to realize that the topics covered in the tutorials are usually covered earlier in the week in the lecture, so this is not the students’ first exposure to the material at hand. Still, we take the most basic approach so that even if they had missed class they should be able to do well. The basic fifty minute class goes as follows. Students come and sit down in groups of 4 to 5 and one of the TA’s (teaching assistants) gives a brief introduction on what to look for in the tutorial as well as any other general information (this is determined in an instructor training session the previous week). Students are then set free to work through the tutorial at their own pace. The TA’s and LA’s that are present then walk around from group to group and provide help where needed. When I am walking around I first try to listen to group discussion on whatever topic they are on to see if they need help with that specifically. If so, I interject with some helpful questions that force them to support their answers. If not, I look to previous answers on the tutorial questions and make sure these are all correct. I tend to ask them questions about their answers no matter what, so that they must justify what they put down. If they were wrong my approach would be to ask questions that will make them realize where they made their error. If they were right, I would purposely question them in a way that they would be forced to defend their answer using what they learned. Usually these types of discussions are very productive. Instructors get a chance to see what and how students are thinking, and in the future they can design an approach that will tend to each student's individual needs. Students also benefit from being forced to explain the answers to us. It is well known that one of the best ways to learn something is to attempt to teach it yourself. This can also be used if there is a single person in disagreement with everyone else about a specific question. If the individual is correct, it provides the perfect situation for them to "teach" the rest of the group (still with an instructor present to mediate). They not only reinforce their understanding immensely, but also many students learn better from their peers. These discussions usually last five to ten minutes and then I move to a new group. After a group is done with the entire tutorial, they are kept until the end of the period, so they may sit around discussing the tutorial further with themselves and the instructors.

The largest problem with the tutorial supplement structure seems to be lack of time. A lot of the tutorials take an hour or more and the 50 minutes allotted is not adequate. The result is that students often are forced to leave without finishing the tutorial. Since they do not have to turn in their work, this often means they are not exposed to certain sections at all, unless they do it on their own time. There are two solutions to this problem. The first is to increase class time, although this is very hard to do in a class that is so demanding for students already. There is then the issue of teachers and assistants as well, as it would require a lot more help from them on a weekly basis. As it was, we ran two rooms of tutorial sections for an entire day, so making the sections an hour longer would mean the addition of another full day. The classrooms for this are just not available either, as this was only one of over five introductory physics classes that are taught each semester. The second solution is to restructure the tutorials in a way that allows students to get them done faster, or at least to cover all the most important topics before they leave. This is the most practical way of fixing the problem, as it is fairly easy to do. Ideally, each tutorial should cover a bit *more* material than they do now, but it should be reorganized so that all the main topics or laws are covered in the beginning. Then, the rest of the tutorial would deal with an abundant amount of applications which would be very relevant but not absolutely necessary to cover. This would allow everyone to get through the most important aspects, while also giving the quicker groups plenty more work to do after they finished the first part. I will demonstrate how this is done in the example tutorial I provide later.

The other problems I seem to encounter regularly are with the tutorial questions themselves. Some of them have good goals, but are worded in ways that are confusing to students. There seem to be many parts to tutorials that could be improved on, and this is another thing I will address in my example tutorials. The tutorials we currently use also have a lack for formulas. This is in many ways on purpose, although with the way that the class is structured, this sometimes leaves students with a gap between their conceptual understanding (which tutorials develop really well), and their ability to solve problems (which is developed on textbook problems). Students are tested on their knowledge of physics in a great part by their ability to do problems on the exams. The conceptual knowledge is more important, but the application of this knowledge is a critical part of performing well. The tutorials work very hard to build this conceptual knowledge, but do not attempt to fit it to problems or formulas much at all. Part of the tutorial method that I have not discussed is the homework supplement that is included with these. This is not the focus of this paper, but would provide an excellent opportunity to make this connection. If the homework assignments were redesigned to make the connection between the formulas given in lecture and by the textbook, students would be able to develop a strong conceptual understanding and then see how this *leads* to the formulas they use for problem solving. Also, test questions should be designed to test both of these skills. Some questions should focus entirely on material taught by the tutorials and involve explanations instead of equations. This would give a better all around evaluation of each student’s specific skills.

The tutorial that I seemed to find the most problems with was the one that first introduced magnets and magnetic fields. The questions in the beginning treated students as though they had never seen magnets before, asking them to divide various materials into groups, based on their interactions. With no real guidelines on how they defined these groups, the first page seemed so basic that it confused students more than it helped them. This even caused confusion with the instructors when we did the tutorial in our training session. The comparison to electric fields that it made was a good point, but I think it was introduced too early and it slowed students down a lot. Sections like these that are too confusing or so basic that students have difficulty determining their significance should be removed from the tutorials all together. For all of these reasons, I chose magnets and magnetic fields to be the example tutorial I provide. I tried to focus on making it easy for students to relate to, and at the same time tried to make it very straight forward, so that one topic led into another. I made sure to cover the most important topics early, and then go on to more advanced relations and interesting applications. This tutorial is longer than the ones we used in class, but hopefully it will flow a lot better. Also, since the important parts are in the beginning, it doesn't matter if students do not finish completely. Ideally, students should be given more time to do it so that they can work through everything, although this is asking a lot, and is not absolutely necessary. The smaller indented type explains my goals for each question, and what kind of answers I am looking for. Most of this information would be provided in an instructors' edition so that they could use it to prepare before class, but some of it relates to this paper specifically, citing some of the major modifications I have made.

Introduction to Magnets and Magnetic Fields

I. What are magnets and what do we use them for?

A. There are various objects on your table, some of which are magnets, metals, or neither. Begin by taking two minutes to play around with different combinations of the objects. Decide which ones are "magnetic" and which ones interact with these.

1. Describe some of the interactions that you see. Do the magnets interact with each other? When they do is there an attractive or repulsive force?

> This first step is meant to familiarize students with the magnetic objects that they have on the table in front of them. It's just a chance for students to see which objects are magnetic and get a feel for everything, hopefully noticing the three types of objects that are present. There is no specific answer expected here. This is similar to the first page of the tutorial we used, but it is greatly simplified and combined into a single question, so as not to hold students up.

2. How do the metals that are not "magnetic," (i.e. have no interactions with each other), act when placed near a magnet? Are they always attracted or repelled? Do all of the

metals interact with the magnets? Why do you think that some metals act differently than others? Explain your reasoning.

> The purpose here is to see that not all metals necessarily interact with the magnets, as this is a very common misconception. Also, they should see that the metals that interact are always attracted. They are not yet expected to explain why this is but it's hopeful that they at least observe it. The last question is meant to spark some discussion about why metals may be magnetic. It is not necessary that they know the answer to this yet; however some students may have had some prior experience to give a simple model for the group to understand here.

B. It is easy to see that magnets can have very strong interactions with certain materials. There is some kind of force causing the different objects to attract or repel. Perhaps this could be used to our advantage in the real world. What are some of the ways that you use magnets in your household? What are other applications you might think we could use magnets?

> Students are just meant to think about the practicality of magnets here. This should be an easy question for them, however, it is very open ended and has no limit to how much information they can put. The idea is that when a tutorial instructor approaches them he/she can explain many of the applications of magnets that students do not know about. There are many household devices, as well as large scale machines that use magnets in ways that students haven't thought about. These discussions depend on the knowledge of the instructor, but often will spark the interest of students and give them justification to why they are learning physics. This kind of positive motivation is very important and should be included wherever it can be.

C. When handling two magnets, you can see that different sides of the magnets act differently. If two magnets are stuck together, it takes a lot of effort to pull one off and turn it over.

1. By observation, how many sides of a magnet cause strong interactions with another magnet?

> This simple observation leads to the next question, which defines the poles. Just answering two here should be sufficient.

2. We will call these sides the "poles" of a magnet. Do the poles on the magnet seem to act differently? How many different types of poles would you say a magnet has? Explain your reasoning.

> Again, this is just used to build the concept of poles, hopefully leading students to realize that there are two poles and each one seems to act differently around other magnets. They do not need to know why the poles are there or how they are formed at this point, but they should at least see that the orientation of a magnet is important.

II. Magnetic Field

A. Now we introduce a new concept to understand the physics behind the interaction of magnets. Earlier in the semester when dealing with charge, we used a quantity called electric field to show how separate charges would interact at different positions in space. We now will do the same thing for magnets and define a *magnetic field*. This section will be used to develop the understanding of what these fields look like and how they act.

1. Use a compass and see how it acts near a magnet. Does the marker always point towards or away from the magnet? What does the compass do near the metals? What does the compass do when no magnets are nearby?

> In order to understand the magnetic field created by magnets, we need a tool where students can actually observe the fields. A compass is our choice here because they are a cheap and easy solution and students most likely have seen them before, making them more familiar and confident in reading them correctly. Here they should just observe how the compass reacts near a magnet. Also, it is important that they notice that the compass always points north when no magnets are nearby, as this will be used to calibrate the compass.

2. Describe what the compass does near the poles of the magnet. What about next to the magnet?

> Students are just expected to elaborate a little more here on the behavior near or far from the poles. Hopefully, they will observe that at one pole the compass points towards the magnet while at the other pole it points away. Again, these observations are leading to the bigger picture of the magnetic field, which will soon be developed.

B. Now we need a way of distinguishing between the different poles of a magnet. The pole in which the magnetic field points out of the magnet is defined as the north pole, and where it points in is the south pole. Notice that this is merely a convention, as was the designation of what positive versus negative charge meant. As we progress, you will gain a better understanding for why we have chosen it this way. For now, just accept it as our definition.

1. Take the sheet of paper provided with the enlargement of the diagram above and place a bar magnet over it. Notice that it is labeled with an N and an S, for the north and south pole. We want to make sure that we match the magnet's poles with the diagram. To do this, figure out the orientation of your compass in the presence of no magnets (*Hint: the magnetic field of the Earth always points north*), and then use that to figure out which

end of the magnet is the north pole and which is the south. Then, make sure that your magnet matches the orientation on the paper.

> The goal of this section is to first figure out which part of the compass points north. It is usually the colored end, however in the lab they often get polarized in the opposite direction from coming in contact with a strong magnet. With the given knowledge that magnetic field points out of the north pole they should be able to successfully match the magnet to the diagram.

2. Place the compass at points A-G and draw an arrow pointing in the direction of magnetic field at each point. You should already have figured out which end of the compass points the same direction as the magnetic field so this should be easy. For an extra challenge, try to estimate the magnitude and use longer lines to show greater magnetic field.

> This is simply an exercise of drawing what the compass shows. Even though it is easy, extra care should be taken here to make sure students correctly draw the magnetic field vectors. This is a very important part of the tutorial and needs to be done correctly. If students attempt to draw the magnitude of the vectors, take a minute to discuss with them why they did what they did. If they are incorrect, make sure to lead them to the correct answer before they move on.

3. Discuss with your group the shape of the magnetic field. Does it look like anything you've seen with electric fields? If so what was it?

> The point of this question is just to spark some discussion. The idea is that the magnetic field has a similar shape to an electric dipole. Students do not necessarily need to remember this, but if someone notices the similarity it may help the group to see the shape. This will be addressed again in the following section, so if students do not get the answer here it is no big deal.

C. Now take the second sheet provided with the two spaces for magnets. Place a bar magnet on the top space and use the blue pencil to draw the magnetic field at each point just as before. Next, move it to the bottom and do the same for all of the points, this time using the green pencil. Last, place a bar magnet on both spaces and use a red pencil to draw the overall magnetic field at each of the points.

> I decided to use colored pencils for this part so that students can really see how the vectors of the magnets add up. By using different colors they can see what happens with each magnet individually while at the same time looking at the combination of both.

1. Describe what you see and sketch in the lines on the diagram above. Do the lines appear to be related in any way? Explain.

> Here, the students are asked to analyze the relationship between the different lines that they have drawn. What they should easily be able to notice is that the red line is always between the blue and green lines. Whether or not the lengths of the lines work out correctly is beyond the scope of this assignment, but is students can give a fairly accurate estimate of the magnitude it is encouraged.

2. Would you say that magnetic field lines can be superimposed? What does this mean?

> This question is meant to lead students to the fact that magnetic fields, like electric fields, can be superimposed. If they didn't catch on to this fact in the previous question, this should be enough of a hint to point them in the correct direction. Also, if they don't understand what this means this should be a good indication for instructors to discuss the physics with them.

3. Does the magnetic field of one of the magnets *change* the magnetic filed of the other or do they just overlap? Explain your reasoning.

> Again, this is for students having difficulty with the idea of superposition. It is really important for students to know that one magnetic field does not simply change another (unless it is strong enough to actually change the properties of the magnet through torque on the dipoles, but this is not the point of the question).

III. Extra Topics Relating to Magnets and Magnetic Field

Before moving on to this section, be sure to check all of your answers with an instructor!

> This is the extra section that I discussed earlier in the paper. All of the students should be able to make it at least to this section, even if they are having trouble with parts or moving slowly. This way, everyone in the class gets to cover the most important parts of the tutorial, and will be able to get the most out of it. For the groups that move faster, this provides something to do for the rest of class, and provides them with more difficult topics that may give them a better understanding of the physics at work. Also, it tells them to check with an instructor before they move on. This is very important as it gives us the opportunity to go over any confusion they had on previous parts, and provide them with a little extra information that may help on the following more difficult concepts.

A. What we just sketched in the previous section were magnetic field point vectors. Now, let's trying composing the magnetic field lines that represent the bar magnet. These are much more commonly used to represent magnetic field because they provide a more complete picture of the field.

1. Begin by placing a magnet on the single vector sheet from earlier, and placing a compass at point C. Move the compass slowly in the direction that the magnetic field points, and as the direction of the compass changes adjust the direction of motion. The line should curve, so if it does not try readjusting. Do this with various starting points near the north pole. Sketch the lines you see on the diagram above.

> This may be fairly difficult for students to do, but that is the point of this final section. Here, I want students to be able to see magnetic field lines, as this is how most textbooks will diagram a magnetic field. Vector notation from the previous part is much less common because it only describes the field at specific points instead of the overall picture. Students will most likely have seen these pictures before in their textbooks or lectures, so that should make it a little easier.

2. Notice how the lines that go through the point vectors point in exactly the same direction as them. Where do all of the lines eventually seem to lead? Why is it difficult to draw the complete line just by moving the compass around, in other words, do you get blocked somewhere?

> When students play around with this enough they should find that all of the lines eventually lead to the south pole of the magnet. They all leave from one end and come back in the other. This is a lead up for the next question.

3. Do you think that there is magnetic field in the magnet itself? If so, what does this say about magnetic field lines? Can they be created at one point and extinguished at another like electric field lines? Explain your reasoning.

> Once students see that the magnetic field lines all point straight in one end of the magnet and out the other, it should help them to realize that the magnetic field actually penetrates the magnet and continues through it. If they are clever they should see that the field is strongest right at the surface of the poles, and this is exactly equal to the field inside the magnet. Then they can see that magnetic field lines have no starting or stopping points like electric field lines (which start and stop on charges), but rather are a series of complete loops. This becomes a very important point in understanding magnetic properties.

4. If you were to move very far away from the magnet so it appeared to you as a single point, what would the magnetic field look like? This is what the field of a magnetic dipole looks like. Try sketching it below. How does this sketch compare to the field of an electric dipole?

> Students have already seen the field lines of the magnet so hopefully zooming out and shrinking the magnet down to a dipole shouldn't be too difficult. This is

meant to give them an overall understanding of shape of the field, especially at long distances. Their drawing should be a double series of increasingly large circles, all going through the dipole at the center. The last question is meant to show that the word dipole actually refers to this shape, as magnetic dipoles and electric dipoles look exactly the same, even though they are created under very different circumstances.

Example of the field of a dipole:

B. Ever wonder why a compass always points north? The truth is that the Earth itself actually acts like a large bar magnet. Surrounding the surface, magnetic field lines all run north and so the small magnet inside the compass will always align itself with the field.

1. A compass can be thought of as a small magnetic dipole. This means that it will line up with any magnetic field present, just as magnets do. Try setting a small round magnet on its side so that it can rotate freely. Now set a compass next to it and move a strong bar magnet near them. Try bringing the magnet close in different orientations each time. Do the compass and the magnet rotate in the same way as you do this?

This was hinted at earlier, but never really in detail. It is important that students realize that the Earth has an ever present magnetic field, and this is actually what we use to describe the properties of magnets. This is one of the weakest parts of my tutorial, but it's the best way I could find to show why compasses work. The small round magnets that we have in the labs can spin pretty easily, so with luck students will see that a large bar magnet has the same effect on both the magnet and the compass.

2. This is actually how we define the north end of a magnet, by convention. When placed in the natural magnetic field of the Earth, the end that rotates to the north is said to be the north pole. This just so happens to be the same end that has magnetic field pointing out. When you look at the north pole of the Earth do you see anything odd? Try drawing the magnetic field of the Earth and see where its actual North Pole is compared to its magnetic north pole.

It is important that students realize that this is another human convention that we have assigned to describe magnets. It does not involve any physics, and we could have easily assigned the poles differently without missing out on anything. It is like the assignment of positive charge and its relation to electric field. The second half of the question is very straight forward, as it is important for students to see that the North Pole is actually the southern magnetic pole. If students forget this and try to use the Earth to describe the relation of magnetic fields and poles they may get the wrong idea.

3. Based on the last part, do you think that magnetic field lines like to point in the same direction, perpendicular to each other, or in opposite directions? Think about the small magnets, how do they align themselves? Explain your reasoning.

> This part begins to show the torque that magnets feel when they are placed in a magnetic field. Students should not have a problem seeing that magnets like to line up, and then this should lead to the fact that magnetic field lines try to point in the same direction. This will be an important fact when we discuss torque on magnets in the future.

C. Take the bar magnet sheet once again and this time place a stack of small magnets equal to the length of the bar magnet in its place.

1. Does the field of the bar magnet seem to be different from the field of the small magnets?

> Assuming that the small magnets are made of a similar material as the bar magnet students will see the same field as before. It is important that they get this for the rest of the section to make any sense.

2. Now break off half of the small magnets. In red pencil sketch the point vectors when the half stack is placed at the front of the outline lining up with the north pole, and in blue pencil sketch the vectors when the stack is at the back. What does the addition of the two half stacks yield? Why is this? Explain your reasoning.

> Once again, I wanted to show how superposition works, but this time with a slightly different purpose. The point here is to get students to think of a single bar magnet a little differently. It should provide physical evidence of how we can think of a magnet as multiple smaller magnets.

3. Could we do this for every single one of the little magnets and still get the same total magnetic field for the stack? If so, couldn't we also do this for smaller and smaller pieces of the magnet? How small do you think we could go?

> We now take it a step further and lead them to thinking of smaller and smaller pieces, however I don't think it's necessary to take the time to actually draw all the pieces. The sum should be same either way and we have already shown this.

4. This could eventually lead to us examining the magnetic field of each molecule. The addition of these could then add up to the total field. We can think of magnetic material as just this. Many little magnetic "dipoles" that all produce a small magnetic field. The addition of all these dipoles then results in an overall large magnetic field. What can you say about the alignment of the dipoles in a magnet, in other words, where would the north poles of the dipoles be pointing? What other objects on your table have magnetic dipoles in them?

> I wanted to start with a good description so students can think about what makes up magnetic material. Then, they can discuss the different types of magnetic material they have in front of them, and think about why these act the way they do around magnets. Having a good understanding of the molecular level physics at work can be very helpful.

D. There are different types of magnetic materials, some of which have dipoles pointing randomly in ever direction. Some such as iron can be made into magnets by applying a strong external field that aligns up these small dipoles.

1. Try touching the point of a nail to a strong magnet and then observe how the compass acts near the nail. Does it interact now? Does the compass act differently if the back end

of the nail is touched to the magnet instead? What does the field around the nail look like now? Explain.

> This takes the last part a step further by examining how these dipoles are affected in the presence of an external field. This leads to some interesting effects such as the creation of magnets. If done correctly the students will see that the nail takes on the form of a weak bar magnet. Even more interesting is the fact that the orientation is reversed when the opposite side of the nail is touched to the magnet. This is a big deal as it shows that we can actually choose what orientation our miniature magnet will have. It also explains why we actually had to check the orientation of our compasses as touching one to a magnet could actually reverse its direction.

2. How strong do you think that the magnetic field must have been to create the bar magnets that we use in this lab? Surely making a bar magnet from another bar magnet is not a reasonable process, so these must have been created some other way. Can you think of anything else that may create magnetic fields?

> This is not really that important yet, but it should get students to see that creating a bar magnet is not an easy task with just this understanding of magnets. It leads to the next tutorial topic which will show how currents create a magnetic field, and potentially much stronger ones than we've seen here. Whether or not they get the last question is not important, but I suspect that anyone that has made it this far probably knows the answer already.

3. With this concept of dipoles in mind, let's look at the interaction of a magnet with a piece of iron. We already know that the dipoles of iron are randomly oriented and they can move around to align themselves in the presence of a magnetic field. Using this, can you explain why iron is always attracted to a magnet? What happens on the molecular level that results in it being attracted both either of the poles?

> This is a little more advanced concept but for those that are able to work through the entire tutorial will probably not have difficulty with it. These are the kinds of questions physicists ask when they encounter the many effects of magnets. Students that are able to conceptually understand physics at this level will be able to work through most problems that deal with the topics covered in this tutorial. This conceptual understanding is exactly what we are after when we teach physics, as it shows a much greater understanding than simply solving problems.

End of tutorial.

This tutorial is meant to give students a basic but fairly thorough understanding of magnets and magnetic fields. I tried to provide a detailed explanation for every question I asked or topic that I addressed, so that instructors using this can understand the purpose of each section and what it leading to. It is meant to be easy enough to be used in any second semester introductory physics class, either algebra or calculus-based. The only prior knowledge students need to have is basic vector notation for the magnetic field diagrams, and some on electric field for the comparative questions. Also, remember that the material we tend to cover in the tutorials is what has been discussed in lecture for the previous few days. The structure was designed so that slower students would still be able to complete the most important sections of the material, while accelerated students would be able to see some more advanced applications. Again, longer sections would beneficial to students, but the resources do not make this easy to do. If they ever do provide the opportunity, however, it would definitely be a great change to make.

Unfortunately, time has limited me to only developing this new method and tutorial for magnets, and I have not yet been able to test its usefulness in an actual class. This would make for an excellent project for the future, and would prove the significance of the changes that I've made to the current method. Someday, I would like to thoroughly analyze all of the tutorials and provide a complete set for both semesters of introductory physics, and then test them in a real classroom setting. Also, I would like to develop the accompanying homework sets that follow each tutorial. I think these could provide a very important piece of the framework of a student's understanding of physics, and may fill in the link that is missing between conceptual understanding and problem solving skills. Surely, these studies already make up a large piece of the field of physics education research, and these tutorials are a method that can still be greatly researched and further developed.

Works Cited

McDermott, Lillian. "How we teach and how students learn – A mismatch?" University of Washington. Am. J. Phys., pp. 295-298, Vol. 61, No. 4, April 1993.

McDermott, Lillian and Peter S. Shaffer and the Physics Education Group. Tutorials in Introductory Physics. Prentice-Hall, Inc. New Jersey, 2002.