The Effects of Classroom Structure on Student Learning in Introductory Physics

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Final paper
Physics 199
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INTRODUCTION

A significant issue in education reform today is the effect of classroom structure on the cognitive development of students. In my study, I observe how the environment of a classroom, specifically a group work setting, affects the learning process. I study the dynamics in a college level physics course's weekly discussion sections which incorported group work and compare them to the dynamics of the traditional tutor led sections. While a variety of disciplines have historically examined classroom dynamics, it is only relatively recently that physics, as a discipline, has begun to explore the effects of classroom structure on cognitive development. As a result, I draw upon both physics and other discipline based studies as a backdrop for my own. In general, I explore how changing the structure of a classroom affects the inter-personal dynamics, which in turn affect learning. Specifically, I explore the importance of feedback in the learning process, and how it is induced by a modified classroom environment.

BACKGROUND

Changing the physical structure of a classroom is one way to alter the environment of a classroom. The classroom structure that I examine in my study was group work. This structure is recommended by education researches such as Ann Brown and Tim Koschmann, who support a constructivist[1] pedagogy (Brown 1992, Koschmann). They support the interactive environment of group work, which allows students to control their own learning and presents them with direct feedback in the learning process.

In my study, the group work structure consists of students breaking into small groups, typically 3 to 5 students per group. Students work together to accomplish a set task. During this process, students are encouraged to discuss with others in their group. Often they will brainstorm and discuss solutions of the assigned problems. This provides an opportunity for classmates to help each other with their misconceptions. "In general, any group member may clarify, expand, restrict, or otherwise alter a topic; it is not static but dynamic and emergent" (Koschmann, p. 15). In contrast to a traditional instructor led environment, the

instructor acts as a tutor and roams around the classroom and observes the interactions of the group. For the most part, the tutor stays in the background and oversees the group work, however, he/she occasionally intervenes in order to answer students' questions or steers a group in the right direction. Although it may be subtle, the role of the tutor is an integral part of group work.

Defining the role of the tutor is essential to making group work successful. The role of the tutor must change according to the appropriate classroom structure. "The tutor should be more facilitory and less didactic, more guide-like and less directly instructive than a conventional tutor" (Koschmann, p. 2). This allows the students to be active during group work and have control of their own learning. They are able to define their own paths of learning. The tutor is there as a guide for their journey. In general, the tutor controls the environment of the classroom, while the students control their learning.

Conversely, in a typical classroom setting the teacher controls the enviroment of the classroom. In a traditional classroom, the learning process is designed for knowledge to be transmitted from the instructor to the student. The teacher controls what the students learn and at what pace they learn. These conventional strategies create a passive learning environment because the setting does not foster student interaction. An environment such as this does not encourage students to actively process knowledge. Instead, student interactions "typically attempt to draw out the adult's 'correct` answer, rather than try to construct new knowledge (i.e. engage in sense-making activity) for themselves" (Sandifer, p. 28). The learning that occurs in group work, on the other hand, is controlled by the students. "Students answer their own questions and are accountable for the quality of the questions asked" (Brown & Campione, p. 124). This responsibility causes students to reflect upon what they think and say.

The act of verbalization, or voicing thoughts aloud, is a key component of group work. It allows students to reflect on their own knowledge. Students may acquire an operational[2] understanding of class material by reading a textbook or attending lectures. However, through the act of verbalization, or explaining the material to another person, students may

be motivated to think more deeply about the material. These acts of reflection augment students' abilities to analyze and sythesize, leading students to deeper understandings of their own knowledge. In turn, they may come to a better understanding of the material, and attain a more formal (or expert level) understanding.

In group work, students take ownership of their thoughts by verbalizing them to the members of their group. They must then defend their beliefs when challenged by other students. It is often during this process of justifying their claims that students either, "reveal many misconceptions and examples of incomplete understanding " (Koschmann, p. 4) or come to realize the basis for their own beliefs and / or understanding. Either way, this environment encourages students to think about their own thinking and reflect on what they do and do not know. Therefore, not only does group work help solidify student understanding, but it also helps them develop their skills associated with learning, such as identifying their own level of understanding.

In the traditional classroom setting, these interactions are not typically fostered. In a passive environment, students are not asked to reflect. Students may not be able to determine their own error in reasoning. In the group work setting, collaboration and coordination require these interactions. These interactions allow students to learn from others around them.

COMPARITIVE STUDIES

In order to set up my own study, I used past studies, which focused on interactive education in a variety of curricula. My work builds upon the work of Ann Brown who created an interactive environment in the classroom (Brown & Campione). Her research focused on changing the environment of a classroom to create "communities of learners". She describes how to "restructure classrooms at many levels including designing curricula, introducing new roles for teachers, students and researchers, and reconceptualizing assessment" (Brown 1992, p. 143) to develop these communities of learners. In one of her studies, she develops the concept of reciprocal teaching. Reciprocal teaching is a teaching method that uses group work

to foster student interaction. Students divide into groups, and each take on a specific role in the group. In the learning process, students each take turns leading the group. It is this method that allows students to become teachers and distributors of knowledge. Ann Brown states that an environment with reciprocal teaching is engaging to students and "everyone is seeking consensus concerning meaning, relevance, and importance" (Brown & Campione, p. 112). Ann Brown found significant results from her study. She states that "[r]eciprocal teaching groups improved daily independent comprehension scores from approximately 35% to 80% correct, compared to a variety of control groups that did not improve significantly" (Brown & Campione, p. 114). Even 12 months later, the reciprocal teaching groups' scores were still high. It was my objective to create a similar interactive environment to study the effects of group work in physics and see what effects it has on student learning.

Other research that I considered for my own study is that of Douglas Barnes & Frankie Todd (Barnes & Todd). They study how talking helped students learn and make meaning, especially in group work. "Through talk the learner can not only reconsider the experience itself but also reshape more generally his or her ideas about such things, ideas previously held in a vague and ill-defined way" (Barnes & Todd, p. 11). They discuss the influence of classmates' opinions on students, and how tutors can take on guide-like roles. They specifically discuss how "[s]mall group talk encourages exploration of ideas, rather than the presentation of certainties" (Barnes & Todd, p. 15). This is a key idea in my own research because group work would give the students an opportunity to expand on and challenge the certainties presented by teachers in lecture. They would be able to explore the material and have an opportunity to grasp the concepts through discussion. "If teachers rely too exclusively upon presenting material to students and then testing their grasp of it through questions, they are very likely to underrate the part that students' own knowledge and ability to make sense of the world can play in learning" (Barnes & Todd, p. 17).

A recent study in physics education that was performed in college level mechanics classes reported on the difference between IE (interactive-engagement) methods in the classroom and traditional methods. Researcher Richard Hake used two different types of

standardized tests in order to track the improvements of the physics students taught by each method. There were significant improvements in the classes, which used interactive learning techniques[3] than those in the classes using traditional methods. Based on these results, Hake concludes that, "[t]he conceptual and problem-solving test results strongly suggest that the classroom use of IE [interactive-engagement] methods can increase mechanics-course effectiveness well beyond that obtained in traditional practice" (Hake, p. 71).

The evidence from Hake's research supports past findings in physics education. Hake notes that "Ohio State, elementary-education majors taking an inquiry-based course did better than students enrolled in a conventional physics courses for engineers on both a synthesis problem and an analysis problem" (Hake, p. 68). These results suggest that interactive physics education may lead to a better understanding of the material than traditional physics education. However, more investigation is necessary in order to pinpoint what *causes* this discrepancy. Hake offers some suggestions for future physics education studies about methods of assessment. "In my view, the present survey is a step in the right direction, but improvements in future assessments might be achieved through . . . observations and analysis of classroom activities by independent evaluators . . . and use of E&M concept tests, and questionnaires which assess student views on science and learning . . . " (Hake, p. 71). Much like Hake's suggestions, this study focuses on evaluating the learning that occurs in an interactive classroom environment versus a traditional environment through classroom observations and E&M concept tests. However, it goes more deeply to understand the structure of the class and what causes the change.

PHYSICS 1B

This study looks at the data collected in a Physics 1B (Thermodynamics / Electricity and Magnetism) tutorial section. The majority of the students who took this class are pre-medical students who have already completed Physics 1A (Mechanics). The class ran a total of ten weeks, and my study focused on the latter seven weeks, which covered Electricity and Magnetism. (The first three weeks of the class covered material on Thermodynamics.) Although all attendance was optional, the general set up of the Physics 1B class consisted of

three lectures per week, one two hour problem session per week, an occasional laboratory (twice per quarter), and one tutorial section per week. The tutorials are a recent reform to the Physics 1 series. The tutorials were added in the last two years to compliment the analytic focus of the class with a conceptual basis. They offer students an opportunity to solve concept-based worksheets in a small classroom setting of approximately 20 people.

TUTORIALS

A typical tutorial section begins with the tutor passing out the tutorial worksheets which emphasize conceptual understanding (see appended tutorial). Next, the students quietly look over them for about 5 minutes and then the tutor begins to goes over the answers. The tutor begins by asking the class for a suggestion on how to begin the problem. If no one volunteers this information, the tutor shows the class on the chalkboard how to solve the problem. Then the tutor asks if there are any questions. If there are none, the tutor moves onto the next question, allowing the students another 5 minutes to look at the problem and repeats the process throughout the 50 minutes. There is an answer sheet to the tutorial questions that is handed out at the end of class.

RESEARCH

At the time of my study, six tutorial sections were offered. Four of the tutorials were taught on Wednesday by a tutor who had graduated from Columbia University, and the other two tutorials were taught on Thursday by a tutor who was finishing up her undergraduate Biology major at the University of California, San Diego. Mainly, I observed the latter three Wednesday tutorial sections which were held at 2:30pm, 3:35pm, and 4:40pm. In my study, the 1:25pm and 2:30pm Wednesday tutorial sections were changed to incorporate group work. During group work, the students formed into groups of three. In these groups, students worked together to solve the problems on the tutorial worksheets. They read the problem aloud and then identify what is happening in the physics problems. Each member of the group adds his or her thoughts to the discussion, and they work together

until they reach an answer. It is not unlikely that one group will ask another group for help. If students still cannot figure something out, they are able to ask the tutor for help.

ROLE OF THE TUTOR

The role of the tutor is defined much as it is described in the Background section of this paper. In group work, the tutor's role is different from that of the traditional tutorial sections. The tutor does not stay in the front of the room, but rather roams around the classroom and helps those groups who have questions. The tutor does not tell the students the correct way to solve the problem, but rather he/she uses methods such as Socratic questioning in order to guide the students to the correct answer. The tutor may also observe groups in order to see what is their level of understanding of the concept.

DATA COLLECTION

The four Wednesday sections were observed. In each tutorial, two leaders (the original Wednesday tutor and a fellow researcher) led these tutorials. The roles of the instructors as tutors changed according to the structure of the classroom (tutor vs. instructor). My role was mainly observational in order to collect data. At times, I would become a participant-observer and tutor during the group work or present a problem at the chalkboard in the traditional sections. This allowed me to gain multiple perspectives for my study. I gathered data through a variety of methods in order to attain an understanding of the classroom dynamics on both an individual (moment by moment) basis and a global level. At the beginning of my study, I focused on the overall classroom dynamics in both of the traditional and group work classroom structures. Later, I focused on specific interactions. I found three main types of interactions: student/teacher, student/student and group/group. I captured my observations by writing field notes after class, which often incorporated the quotes and statistics that I had taken during the section. I also reviewed comments made by the tutor and the fellow researcher in their field notes. I chose to take field notes for reasons noted by Koschmann. "Field notes and certain high-level representations of the group's deliberations are helpful in

suggesting likely places the interactions of the type [ex. reflection] we have been describing might occur" (Koschmann 6). In general, he encourages the use of field notes to capture the dynamics of the classroom. With this data, I am able to explore the interactions that lead to students' cognitive development and track feedback that facilitates this process. For quantitative data collection, I recorded students' attendence, and issued pre-tests and post-tests[4].

DATA / ANALYSIS

The purpose of my study was to identify how changing the structure of a classroom affects the dynamics and interactions of students and tutors, and how those dynamics affect the learning process.

STUDENT INTERACTION

I found that by changing the physical and social structure of the Physics 1B tutorial sections, the dynamics and interactions in the classroom changed noticebly. Before my study began, all tutorial sections had been run as tutor led discussions. When two of the tutorials sections were converted to group work, it was apparent that students were not initially comfortable working collaboratively. Group work was a new mode of learning for many of these students, and it took some time for them to become adjusted. In essence, we were in the midst of developing an interactive environment, one very different from the traditional format of student learning in physics. I captured some observations from the first group work tutorial in my field notes. "[The tutor] told the students to work in their groups on the next problem. Absolutely no one moved to form a group" (Polityka, 10.13.99). The tutor paused, a bit stunned that no one was forming groups, and then told them to group up again. This time, "[a] slight russle of chairs occured as students paired up mainly to the person next to them. Those at the random desks made no effort to find a partner. . . I never really heard much more than a slight whisper during this group work" (Polityka, 10.13.99). The next week, a researcher noticed an improvement in the dynamics of the classroom. "What I heard was somewhat inspirational. A low din started, and the students started looking at each other's papers, discussing, debating, and drawing conclusions . . . it is one of those environments

where you can walk in and know that it is good, educational, and engaging for the participants" (Finkelstein, 10.20.99).

The following week, even a greater improvement was noted as the tutor described the classroom as, "abuzz with students trying to solve tutorial problems" (Kagnoff, 10.27.99). And the researcher noted that "[s]tudents were perched all over the room working on problems. I wandered around the table, the side desk, the counters speaking with students. Mostly they all paired up and worked well in groups. I overheard many students working through problems as I had suggested: to read it out loud, identify where it is from in the chapter . . . (by the end this had once again broken down, but students were asking each other, challenging ideas, each other etc.)" (Finkelstein, 11.10.99).

Although initially some students were a hesitant to interact in the group work environment, it was clear that in the span of a few weeks, they overcame their reservations and began making contributions and initiating questions and answers thereby creating an active learning environment for their group. Interactions that occured in the group work tutorials were significantly different than those interactions in the tutor led tutorials. While most of the students were actively contributing and interacting in discussions during the group work tutorials, only a few assertive students particpated in the tutor led discussions. The tutor observed that "whereas groups facilitated the quieter students to express themselves to their classmates and to ask one-on-one questions of tutors, lecture-style seemed to further inhibit more reserved students" (Kagnoff, 10.20.99). "[Only a] couple of students dominated the class when it came to asking and answering questions, and others rarely spoke up" (Kagnoff, 11.17.99). "It was clear that in comparison to the group-method tutorials, fewer overall questions were asked on the part of the students" (Kagnoff, 10.20.99). A fellow researcher noticed the difference in dynamics of the two types of tutorials as well. "In a large scale lecture, one student will answer or it is easier to accept the silence. In the smaller group it becomes a more personal interaction" (Finkelstein, 10.20.99).

An unexpected result of modifying the tutorial structure was that one of the control groups, the tutorial style format, took on a hybrid state. The 3:35pm tutorial section exhibited

both group-like dynamics and traditional classroom dynamics even though it was ran as a traditional tutorial section. Not only did "some people paired up to do problems, although they were not asked to do so" (Kagnoff, 11.11.99), but the level of student questions and responses were amazingly high compared to the other lecture style tutorial. The tutor identifies this descrepancy and notes that

> . . . in one of the lecture-method sections that had approximately 6 students in attendance, the tutorial seemed to proceed more like a group-method tutorial in that all of the students asked questions of myself and each other. It is difficult to determine if these particular students are especially vocal or if the small class size somehow facilitated greater interaction with one another. The other lecture-method tutorial had approximately 10 students in class and the students did not participate as actively (Kagnoff, 10.20.99).

Although it was not possible for me to take statistics for the group work tutorials because of their structure, I was able to capture statistics of student interactions at one point which compared the classroom dynamics of the hybrid (3:35pm) and traditional lecture (4:40pm) tutorials.

Section 3:35pm (hybrid)
Researcher's questions = 67

	Questions:	Responses:	Nods:
Student 1	0	2	2
Student 2	3	2	2
Student 3	9	13	3
Student 4	4	17	8
Student 5	0	1	0
Total	16	35	15
Avg /student	3.2	7	3

Note: All students are women in this section. Student 1 left 7 minutes early.

Section 4:40pm (lecture)

Class Observations
Tutor questions = 8

	Questions:	Responses:	Nods:
Student 1	0	0	0
Student 2	0	0	0
Student 3	0	0	0
Student 4	0	2	0
Student 5	2	0	0
Student 6	0	0	0
Student 7	0	0	0
Student 8	2	3	0

Student 9	1	0	0
Total	5	5	0
Avg/Student	.56	.56	0

These statistics show the total number of questions per student was greater for the hybrid 3:35pm tutorial section, 3.2, which was composed of only five students, versus the traditional tutor led discussion, 0.56. One reason why this may have occurred is because Student 3 was very active in the tutorial section. Often she would raise conceptual questions to the tutor and fellow students. This would create a casual open environment in which fellow students began contributing. With this feedback, the tutor asked more questions, which in turn led to more student responses. Typically, in tutor led discussions, this cycle died out quickly as can be seen in the 4:40pm section where the tutor's questions were greeted with silence. "I felt the stark silence to my questions and I found myself just telling them the answers" (Polityka, 10.27.99). There was no feedback from the students to the tutor and so interactions stopped before they ever really even began. When students don't respond, tutors stop asking questions. This effect is apparent comparing the number of tutor questions asked in the 3:35pm tutorial versus the 4:40pm tutorial: 67 versus 8. However, when there was feedback both tutors and students benefited by the interactive environment which was created.

FEEDBACK

The feedback that occurred in the group work sections due to changes in the classroom structure allowed the tutor to identify students' misconceptions and recognize what motivated or frustrated the students. As a result, the tutor was able to use this feedback to improve her own teaching skills. The tutor was able to clearly see which teaching strategies were effective and motivational for the students and which ones were confusing and frustrating to the students.

On the other hand, the lack of feedback in the traditional tutor led discussions prevented the tutor from identifying where students were having trouble understanding certain concepts. When leading a traditional section, I noted that "[whenever the tutor] or I would ask a question, there wasn't any response. I'd ask a question such as , "What's the charge?" I'd point to the answer [on the chalkboard] that we had just figured out and still no one would say the answer. I noticed that when I was teaching, I really couldn't tell what was being absorbed and what wasn't. I'd turn around and look for eye contact. It was often times with the same one student . . . I really didn't know if students could "see" it." (Polityka, 10.27.99). The tutor notes her own experience in her field notes that "it was difficult to determine where individual students might be having difficulty with the material. Therefore, it was difficult . . . to intervene and provide help to students unless a particular student was not shy about asking a question" (Kagnoff 10.20.99).

During the tutor led tutorials, I noticed that

> There was very little response to [the tutor's] questions. And if there was a response, it was typically one word, whispered softly. For instance, at one point, I heard a voice actually squeak it was so soft. The students didn't seem comfortable enough with the material, or perhaps themselves, to answer her question. [S]he would tell them the answer ending with a phrase such as "right?" Then students responded with a few nods or soft 'uh-huhs' (Polityka, 10.20.99).

Also,

> "[i]t appeared that the students didn't get very far working on the problems on their own. When we went over the problems on the board, a few of the students were concentrating hard on trying to learn the answer, while others were copying down what was written. I didn't notice anyone checking their work with what was being solved on the board. In fact, I didn't really notice anyone really writing anything on down during their individual work time" (Polityka, 10.20.00).

I had a difficult time judging if the students were understanding what they were being taught. "Most of the class was writing down [the researcher's] derivations on their paper and so it was difficult to see if they had absorbed the concept" (Polityka, 10.20.99). There were no noticable

reactions to what was being taught. There was nothing for me to gauge whether they were grasping the material. This lack of feedback in traditional tutorials caused the teaching process to be very one-sided, and the learning process to be passive.

On the other hand, the group work tutorials were filled with interactions. Not only was there personal communication between tutors and students, but the tutor was able to identify moments of student learning. At one point during class, the tutor pulled the researcher aside to report that a young woman was benefiting from the group work. He writes about her encounter in his field notes: "The young student had the right idea, but lacked all confidence in her answer. By voicing her opinion and being validated by the others, [the tutor] was sure the student had improved" (Finkelstein, 10.20.99).

I captured a similar interaction between two group members and the tutor in my field notes. Student 9 has the right answer, but is hesitant to share it with the tutor:

> **Student 9: Is that right?**
> **Tutor: Yep!**
> **Student 7: They both go to zero so it's just like a piece of wire. Why it's so easy!**
> (Polityka, 12.1.99)

Clearly, this feedback is very important even to students who have the correct understanding of the material. It gives them an opportunity to voice their thoughts and check them with others around them, be it a tutor or other students.

IDENTIFYING MISCONCEPTIONS

Often it is through these tutor / student interactions which reveal student misconceptions. The tutor noticed that unlike the traditional tutorials, during the group method tutorials " . . . students felt comfortable asking the tutors questions" (Kagnoff, 10.28.99) and " . . . asking for help when they were stuck on a problem . . ." (Kagnoff, 10.20.99). The researcher felt more capable identifying students' misunderstandings in the group work setting than in the traditional tutorial setting. He described an experience that occurred during

the group work tutorial in his field notes. " . . . I had a student explain his reasoning behind why he took the derivative of the cosine θ . . . He gave a misleading answer . . . A quick discussion set the fellow and the group straight" (Finkelstein, 11.17.99). The error was not obvious, however the interaction allowed it to become visible. It was the student's interaction with the researcher, which allowed his misconception to be noticed. This, in turn, allowed the researcher to correct the student's error through personal interaction, from which the entire group benefited.

Although there were often several groups in the room during a tutorial section, in general, the researcher felt that both he and the tutor could reach the all of the groups while having plenty of opportunity to target misconceptions. "Even with 6-8 groups, [the tutor] and I worked the room pretty efficiently. Often I had to ask students what the answer was. Often they'd arrived at the wrong answer and moved on. It is easy for the students to convince each other of the right answer or the wrong one. So, spending some time with them was helpful and productive" (Finkelstein, 11.10.99)[5].

STUDENT ATTITUDE

The feedback that took place between the tutor and students during group work changed some students' attitudes toward learning and allowed the tutor insight into this transition. Within a few weeks of my study, I noted a change in the classroom atmosphere for the group work tutorials. A definite interest in the material existed that had not been present in the past. The students seemed more enthusiastic and motivated than they had in the previous tutorials. The researcher states that, "[the] students were generally eager, and got straight to work when [the tutor] placed the tutorial down" (Finkelstein, 11.17.99). Some students even stayed after the class period had officially ended in order to ask questions or finish working out a problem with their group. One girl in the 1:25PM section started staying for the 2:30PM section too and would use the 15 minutes passing period between class to get

one-on-one help from the tutor. In fact, she did this for 5 weeks. Her behavior was very different from the students in the traditional tutorial sections, where it was not uncommon to see students leave class the minute the class period was over even if the tutor had not finished talking (occasionally, even earlier). At times, an entire group from the group work section would stay after class in order to finish up the tutorial worksheet. The researcher notes that "[n]ot all the student groups finished all problems . . . one group stayed into the next session" (Finkelstein 10.28.99). Whereas, a group of students associated with the traditional tutor led sections would often skip tutorials and stop by at the end the class to pick up the answer sheet then leave.

The researcher began receiving explicit feedback from students during the last few weeks of the group work tutorials. He states that there was "[g]enerally a good response. Students have started thanking me as they leave" (Finkelstein, 11.4.99). He also describes an experience that he had with a student who enjoyed working in groups with the roaming tutor and researcher. "On his way out one of the students came to me and said, 'You should get the most needed and helpful TA award' I thanked him and was glad
I could help" (Finkelstein, 11.10.99). In the tutor led discussions, no students approached the tutor, researcher or me with such responses.

During one of the modified tutorial classes, I helped a group solve one of the problems on a tutorial worksheet (see attachment). After we had solved the problem through geometric interpretation, a girl began asking me questions about integration.

> Even after they realized that explicitly solving the integral was not necessary, one of the girls in the group continued to ask [how to] solve an integral with a curve. I outlined how to integrate a function, but she asked if we could do an integral together. I mentioned that she probably wouldn't need to know how to integrate this for the quiz, and she told me that she just wanted to remember how to integrate. I showed her a quick example integrating x^2. Another guy in the group stopped what he was doing to follow along. My impression was that their desire to understand integration was a result of curiosity and not in preparation of their weekly quiz (Polityka, 10.20.00).

A deviation from the weekly physics topic such as this did not occur in the tutor led discussion sections. As mentioned previously, there were very few questions that were asked in these tutor led discussions. Rarely, were questions repeated if they weren't accurately answered by the tutor. And lastly, there was no opportunity to deviate from the set curriculum because the tutor leads the students down a specific path.

STUDENTS CONTROL LEARNING

In group work, students developed the ability to control their learning. They were not only able to explore specific issues, but they could set their own pace according to their needs. The tutor noticed how the students controlled their learning. She states in her field notes that

> In general, the students in groups tended to move along at their own pace . . . [They] seemed to want to spend as long as they need on a particular problem in order to fully understand it. This conclusion comes from the fact that students in groups stayed focused on the first 2 problems until they completely understood them rather than hurrying to the other questions (Kagnoff, 11.4.99).

Students are able to focus on areas where they are having trouble. They are able to ask specific questions to others in their group and have the ability to drive the conversation toward information that will aid in their learning. The tutor also states that "overall, they relied more on themselves than on the instructors to come to the solutions" (Kagnoff, 10.28.99). In the process of group work, there is no defined time where the tutor goes over the answers to the tutorial questions. As a result, students who are interesed in knowing the answer take the responsibility to solve the problem and actively persue the answer with the aid of their group. At this time, the students control their learning and decide the point at which they are satisfied with their understanding and should move on to the next question.

STUDENTS AS TEACHERS

Because students depended on themselves and each other to figure out the answers, students took on new roles in which they taught other students. The tutor notes that ". . .

those students that knew more tend to explain concepts to those students who understood less" (Kagnoff, 10.28.99). The researcher recalls in his field notes that, "Often I overheard students checking their answers with each other, justifying their reasoning, or getting stumped and asking for help from each other or the [tutors]" (Finkelstein, 11.10.99). The researcher encouraged this student/student interaction. When he would help a group, he would use Socratic questioning in order to allow them the come to the correct answer. He states that, "[e]very time, they seemed to arrive at the correct answer . . . Sometimes I'd end up explaining something to a group. Often, only one person would get the "ah ha!" As soon as that happened I [would] say to the one, okay now explain that to your collegues" (Finkelstein, 11.4.99). "This worked pretty efficiently, reinforcing their new found knowledge, challenging it, and freeing me up to roam" (Finkelstein, 11.10.99). I capture an example in my field notes where a student took the researcher's explaination and taught it to a fellow student:

> The researcher defines **dA** as a vector with a magnitude. Then talks about **B•dA**. He gets several nods from the group as he speaks, illustrating their understanding.
>
> **Student 8: So since B = 0, the flux is 0?**
> **Researcher**: **Yes.**
>
> Student 9 tells Student 8 that he doesn't understand what researcher meant. Student 8 begins to explain but has his sentence finished by Student 9.
>
> **Student 8: He's saying that area, dA is represented by a perpendicular vector to--**
> **Student 9: the area.**
> **Student 8: Yeah.**
> (Polityka, 12.1.99)

This is a prime example of student coordination. Finishing sentences for one another illustrates a high level of coordination. At this level, students are able to reach a point in which their thinking is synchronized with each other.

The researcher noted one particular student who was a very active group member. This student not only taught his group, but he'd listen and use Socratic questioning to challenge others in his group, modeling the tutor and researcher's roles. The researcher notes,

"He spent some time on each side of the fence with his group, sometimes explaining ideas, sometimes listening to other student's justifications. Occasionally he'd bring up a question about another student's reasoning that [the] student couldn't answer" (Finkelstein, 11.10.99). This group work allowed him to develop his own understanding of a topic through his questions and explainations.

Another time, I documented a different student, Student 6, teaching others in his group by Socratic questioning as well. He used this method to teach other group members how to add voltages:

> **Student 5: Is it voltages in series that you add?**
> **Student 6: Yes.**
> **Student 4: Do you add or subtract them?**
> **Student 6: You add them just like other resistors.**
> **Student 5: So it travels this way?**
> **Student 6: Which way is stronger?** (Socratic questioning)
> **Student 4: Oh! I see.**
> (Polityka 11.17.99)

Student 6 wanted Student 4 and Student 5 to understand the underlying concepts to adding voltages. He chose to lead them to the correct answer, as opposed to just showing them his answer telling them how to solve the problem. Therefore, Student 4 and Student 5 were able to actively figure out the answer with the guidance of Student 6.

CHANGES IN TUTOR'S TEACHING

Group work not only allowed students to learn through teaching, but it allowed the tutor to learn as well. The tutor's teaching style improved throughout the group work tutorials because she was able to see what approaches worked best when tutoring the students in the group work format. In fact, her overall method of questioning students seemed to change. The researcher notes that "[s]he dramatically shifted her style asking student questions, becoming more interactive" (Finkelstein, 10.28.99). I was quite fascinated with how her teaching techniques changed over the time of my study.

> I noticed that her style of lecturing has become drastically more effective. She is friendlier and has become more engaging and interactive. I think that by helping students in group situations previously in the day, she is able to see clearer which explanations work [in the traditional setting (Polityka 11.17.00).

The researcher also noticed that the tutor's lecture style had been affected by the group work tutorials. "[The tutor] has changed her style of lecturing . . . to be somewhat Socratic" (Finkelstein, 11.10.99). Even though this added a twist on our control group, he pointed out that "[t]he up side is that these students are engaged more, and clearly learning" (Finkelstein, 11.10.99). Even the tutor could feel a difference in her teaching. She notes that " . . . I am better able to explain the material more clearly in the last two sessions because I have already gone through the tutorial material with the students from the first two sessions" (Kagnoff, 12.1.99). The feedback that occurred in the group work tutorials seemed to be very beneficial to the tutor. It both permitted the tutor to explain concepts better to students in traditional sections which followed group work tutorial sections than the earlier tutor led sections, and it encouraged the tutor to ask types of questions which were engaging and interactive.

DRAWBACKS

Although, in general, group work tutorials encourage interaction between students, there may be some times in which interaction is actually stunted. A situation such as this occurred once during the group work tutorials. The tutor was busy helping a student and was not able to attend to other groups who were stuck on a problem. At first, the students were busy trying to figure the problem out, however, after time passed and they were still not sure how to solve the problem, they became impatient and frustrated. Unlike the traditional tutorials where the tutor is the driving force, the structure of group work is based on the students' control of their own learning. Therefore, if a group gets stuck and does not have

access to a resource (a tutor or other students who understand the problem), they may feel defeated. This is illustrated below from my field notes.

> **Student 1:** (reads problem out loud) **Oh, wait! There's not "t" in there!** (the equation)
> **Student 10: So what's the difference between these?** (referring to 2 equations) **Student 1: I think it's just this one.**
> **Student 10: Well, it says it has a velocity.**
> **Student 1: There's no time (t). I'll just ask.**
>
> Students 1 and 10 end up waiting for help because the researcher is preoccupied talking to Student 4, the girl from the previous section and the tutor is talking to Student 2. After a bit of time they ask another group if they know how to solve the problem.
>
> **Student 1: What number are you guys on?** (asking Group 2)
> **Student 8,9: Number 3.**
> **Student 1: Do you get it?**
> **Student 9: No.**
> **Student 1: I hate this class.**
> (Polityka, 12.1.00)

At the beginning, Student 1 is very active. She enthusiastically reads the problem outloud and gives offers her opinion as to which equation is the correct one. She still seems interested in figuring out the problem when she asks another group whether they have gotten the problem. In the end, she is frustrated enough to verbalize her feelings, "I hate this class." Afterwards, even the tutor noticed the problem and stated, "While I was able to give these two groups a large amount of personal attention, I was not as available for other groups" (Kagnoff, 12.1.99). As mentioned previously, an aspect of group work is the ability for students to control their learning. However, once the students run out of resources (i.e. themselves, each other, a tutor), the learning process may be stunted. Students no longer feel in control, rather they feel frustrated and stuck. At that point, passive learning, such as a tutor led discussion, is not even taking place. My suggestion to prevent this lull in learning is for the tutor to give some aid to a group and then allows them to work on the problem while he/she roams around the room more. The tutor can then go back to the group a little bit later and see if they still need help. If a group requests a lot of personal attention, the tutor may suggest that they to stay after class for an extra few minutes.

Other difficulties that a tutor may run into are students who are resistant to working with their group. The researcher noticed a girl sitting in a group but working alone. He recalls, "When I approached the single individual she said she was fine, and getting the answers just fine. I asked her to explain it to the rest of the group, but don't expect that she ever did" (Finkelstein, 10.20.99). On the other hand, a few weeks later, the researcher ran into another girl who did not seem to want to be in a group. He noticed, that "[n]ot everyone naturally began in groups, and one young woman in particular seemed to be bothered by it . . . However, midway through class she was busy comparing and explain her answers with her 2 cohorts" (Finkelstein, 11.17.99).

I would suggest that the tutor initially encourage the student to work with their group. If, however, the student still prefers to work alone, the tutor should try to deduce whether the student works better alone or whether the student is not included. If it is the latter, then the tutor may wish to pay more attention to that student and try to make them feel comfortable with his group or the material. Otherwise, the tutor should allow the student to work on his/her own if they work best that way.

The researcher also notes that different formats may be necessary for different educational material or goals. He writes, “It struck me today, that there might be topics which are better done in a lecture format” (Finkelstein, 11.17.99). He found himself explaining the exact same concepts to each group that may have been quicker and just as effective to present it to everyone at the same time. This is especially true if the groups couldn’t begin to solve a problem until they had heard what the researcher had to say. The tutor concurred. She suggests that " . . . the TA/tutor might want to prepare a 5-minute introduction on material he/she feels will help the students move along in problem-solving. This will save time instead of having to stop and explain the same concept to each group in the class” (Kagnoff, 12.2.99).

Overall, if tutors efficiently use their time, they may maximize their contact with students and keep the learning and interactions flourishing. Frustration starts when students

have to wait around for a tutor to help or present needed information or the material is beyond their grasp. Also, tutors need to be aware of the students who are not participating in the group work and be conscious of whether it is beneficial for them to participate. Then, they may decide if and how they should approach the student.

CONCLUSIONS

Overall, I found that the dynamics of the tutorial classrooms were affected by the change of classroom structure. The environments of the traditional and group work tutorial sections were noticeably different. During the traditional tutorial sections, the tutors solved physics problems on the board while the students observed and copied down the answers in their notebook. There were very few student interactions that took place during class even though tutors often asked the students if they had any questions. The tutors noted how they found the setting difficult to receive input from the students. After a small period of adjustment, the environment of the group work tutorial sections had completely converted from a typical lecture style classroom into a productive, interactive setting in which students explored physics topics and collaboratively drew conclusions.

These interactions that took place during group work were beneficial because they provided feedback to both the tutors and the students. Because of this feedback, tutors found it easier to identify students' misconceptions and find out what motivated or frustrated students. They were able to use this feedback to improve their own teaching. Students were able to use the feedback within their groups to help each other identify misconceptions and also to get more personal help on a problem. This environment not only improved students' attitudes toward learning physics, but it encouraged students to come to deeper levels of understanding physics through the verbalizing and justifying their ideas within their groups.

In my study, I also saw how significant the role of the tutor is in group work. The students might not naturally fall into interacting even though the classroom structure set as

group work. The tutor may need to actively encourage students to discuss within their groups and approach those individuals who are not participating. They are also responsible to encourage students to teach one other. They need to delegate their time between groups so that they are able to assist everyone who needs help.

NOTES:

[1] "[The constructivist] model contends that all of our knowledge is the result of our having constructed it. At any time, the corpus of knowledge we have constructed makes sense to us and helps us interpret or predict events in our experiential world. Meaningful learning, in the sense that we are able to interpret and apply knowledge in novel contexts, requires significant mental engagement by the learner" (Mestre, p. 56-7).

[2] I use openational understanding to mean understanding the process, but not underyling theory, principles etc.

[3]"Fourteen 'traditional' (T) courses (N=2084) which made little or no use of interactive-engagement (IE) methods achieved an average gain $\langle g \rangle_{T\text{-}ave} = .23 \pm .04$ (std dev). In sharp contrast, 48 courses (N=4458) which made substantial use of IE methods achieved an average gain $\langle g \rangle_{IE\text{-}ave} = .48 \pm 0.14$ (std dev), almost two standard deviations of $\langle g \rangle_{IE\text{-}ave}$ above that of the traditional courses" (Hake, p. 64).

[4] While these data had been taken, they had not been analyzed at the time of this paper. Subsequently, it has been observed that students attending tutorials made gains on a conceptual survey 10% greater than those not attending tutorial sections. However, there was no statistically significant difference in the measured gains between the modified group work tutorials and the traditional led tutorials.
This paper focuses on the qualitative changes that occur in the classroom. One such change that will be discussed later in the paper is the change of the tutor, herself, due to the group work sections which in turn affected the tutor's approach to teaching in the traditional tutor led classroom.

[5] In the Drawbacks section of this paper, I discuss the effects on student learning in the group work tutorial section when students did not have access to a tutor or a researcher.

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