

Understanding and Encouraging Effective Collaboration in Introductory Physics Courses

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Abstract. Anecdotal evidence from the introductory physics classrooms at Chicago State University suggests that our students view collaboration as an important tool in their learning. Despite this, students often need additional instruction and support in order for collaboration to be effective. In order to aid students in establishing effective collaborations we may be able to capitalize on the fact that students at CSU readily accept the inquiry approach to instruction. In this paper, we present the initial stage of this work. Specifically, we have begun to videotape student interactions in the classroom, interview students about the nature of learning, and develop and administer instruments that assess the value students place on the use of guided inquiry. By utilizing a specific criteria and analyzing the occurrence of specific behaviors in the classroom we can determine the effectiveness of collaboration during group work. Responses regarding how students value the use of questions in instruction indicate the level of feasibility in utilizing peer questioning to promote effective collaboration.

Keywords: collaboration, group work, inquiry, Physics Education Research.

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INTRODUCTION

The benefits of collaborative learning have been well documented in specific populations [1]. In particular, research indicates that collaboration is a valued resource among African American students of low-socioeconomic status [2]. The physics program at Chicago State University (CSU) has anecdotal evidence that students in our introductory courses value group learning and engage in peer discussion and peer questioning very easily. This willingness to collaborate may be a function of our students - CSU is a public, comprehensive, urban institution located on the far south side of Chicago. Demographically, 85% of the undergraduate students identify as Black, 7% Hispanic, 3% White, and 5% other (Illinois Board of Higher Education, 2007).

METHODS AND RESULTS

In order to move beyond anecdotal evidence and assess the type of collaboration taking place in our classes, students in the algebra- and calculus-based introductory mechanics courses were videotaped while completing research-based laboratory activities.

One item that is apparent in analyzing student interaction in one of the classrooms we observed is the

frequent use of questioning among peers. This questioning can take on a number of forms, including the use of questioning by one student to guide another student toward an understanding or the use of questioning to confirm or challenge another student's ideas. The use of questioning can foster effective collaboration because it forces students to attend to statements made by group members.

Transcriptions of classroom videos, analysis of surveys, and transcriptions of interviews with students in introductory physics and physics tutors were used to investigate how our students view the learning of physics.

In-class Collaboration

Videotaping of students in the introductory classroom occurred during the middle of the Spring 2008 semester. Segments of the videos were coded to establish the level of effective collaboration. The data focuses on a specific activity, Equilibrium of Rigid Bodies, conducted in the algebra-based course.¹ Although encouraged to work in groups during this activity, students were not given explicit instruction on

¹ This activity is one of the Research-based Laboratories developed by Kamin, Loverude, Gomez (National Science Foundation - DUE #0341333)

collaboration. There are a variety of criteria that can be used in analyzing how students interact in the classroom [3,4,5]. We based our criteria for effective collaboration on the work of Puntambekar [6]. Collaboration is considered to be effective if (1) all members of the group participated, (2) claims made were confirmed, challenged, or restated by someone else in the group, and (3) a consensus was reached if the group moved on to another section of the laboratory assignment. If the group moved on without reaching a consensus the segment is classified as ineffective, even if the other two criteria were met.

The entire video in which students are conducting the activity was transcribed and coded in five-minute segments. Each segment was classified as illustrating effective collaboration or ineffective collaboration. We also recorded the whether the group received assistance from the instructor, the teaching assistant, or another group and whether or not students asked each other questions during the activity. All question sequences were classified as to whether they were used as 1) a tool to guide a peer to an understanding, 2) a means of clarifying a previous statement, or 3) a means of offering, refuting, or challenging an idea. Of the 23 five-minute segments analyzed 21 of them were marked as demonstrating effective collaboration.

Analysis of the video also demonstrated how student use of questions contributes to effective collaboration. In this excerpt students are discussing a T-shaped board, balanced on a pivot. In the following portion we see Mari asking Deja questions. The group is locating the pivot point for the T-shaped object. When Mari sees that Deja is struggling with the fact that the center of mass and the pivot are at the same point, she asks her a question to help her resolve this issue.

Deja: Where is the pivot?
 Mari: Bam. (points to the pivot)
 Deja: Okay, this is the center of mass. (points to the pivot)
 Mari: ... and also the pivot. So, where is it turning at?
 Deja: It's turning this way.
 Leah: No, where at?
 Mari: From where? From where is it turning?
 Deja: The center of mass.
 Mari: That's the pivot.
 Deja: This is ... kind of challenging.

It is interesting to note that throughout the activity Mari takes on a particular role where she asks the group questions. The other group members also seem to fall into roles naturally despite the fact that roles were never assigned. Leah seems to make sure consensus is reached and Deja reminds the group of specific definitions and concepts. These roles seem to

promote effective collaboration in this group. The next excerpt shows the group deciding how the mass on either side of the center of mass compares.

Leah: (reads worksheet) Predict whether the total mass of the system to the left of the vertical line is equal to the total mass of the system to the right of the vertical line. Explain...
 Deja: Yeah. I think it's equal because if the total masses ... if their forces are equal then their net torque would be zero.
 Mari: When it's up there? What if we took it down and sawed it in half and weighed both sides?
 Deja: It would be equal.
 Mari: You sure about that?
 Deja: Yeah.
 Leah: No, I'm not sure about that.
 Mari: All right. Think about that ... At the pivot point, at the center of mass, if you took it down and sawed it in half would it be the same?
 Deja: Oh, no. I don't think it would be. It said the total mass.
 Mari: Because I would say no,

We see examples of the students asking questions that facilitate discussion in 13 of the 23 segments. The frequency of this use of questioning shows the value CSU students place in using questions as a tool for learning. This view that learning must be an active rather than passive process is a resource that we can utilize as instructors with this population. Table 1 shows the frequency of different behaviors in the entire 23 segments of the video. The analysis shows a group that is working extremely well together based on how often certain behaviors emerge.

Effective Collaboration		91 % (21 of 23 segments)
Restatement/confirmation/challenging of group claims/ideas		91 %
Use of questions 74 % (17 of 23 segments)	<i>to guide a peer to an understanding or to offer another idea for discussion</i>	57 % (13 of 23 segments)
	<i>as a means of clarifying a previous statement</i>	52 % (12 of 23 segments)

Survey Responses

To provide further evidence of the value CSU students place in the use of questioning, inquiry instruction, and active engagement, a survey was designed and administered to students in the first semester of the calculus-based introductory physics

course. The survey contains two scenarios that take place in a physics classroom. In both scenarios, two students work together to complete a quiz on descriptions of motion. However, in the first scenario one of the students guides their partner to an understanding of the concepts needed to complete the quiz by means of questioning. In the second scenario one of the students explains the concepts needed to arrive at the correct conclusion.

The survey asks the reader to decide on which scenario best fosters an understanding of the material in addition to an explanation for the response. It also asks the reader to state explicitly if they think that both scenarios are equally good. Fig. 1 shows excerpts from the survey scenarios.

This survey was administered to thirteen students. The most common response involved students stating that the scenario which utilized the questions best fostered an understanding of the material: 54% of the students chose scenario one, 23% of the students stated that the two scenarios were equally good, and the remaining 23% of the students chose scenario 2. These results provide evidence that the majority of CSU students do value the use of questioning in instruction.

<p><i>Scenario 1</i></p> <p>...</p> <p>Clarissa: I think it is positive because the cart is moving in the positive direction.</p> <p>David: What direction is the velocity in?</p> <p>Clarissa: The velocity is in the positive direction.</p> <p>David: Is the speed increasing or decreasing?</p> <p>Clarissa: The speed is decreasing.</p> <p>David: If the speed is decreasing, what does that tell you about the direction of acceleration?</p>
<p><i>Scenario 2</i></p> <p>...</p> <p>Frank: I think it is positive because the cart is moving in the positive direction.</p> <p>Erica: The speed is decreasing – that means that the velocity and the acceleration must be in opposite directions. So because the velocity is positive the acceleration must be negative.</p>

FIGURE 1: Excerpts from survey scenarios.

Written explanations revealed that students who chose scenario one appreciate this instructional method because it helps to break the problem into smaller pieces. One student stated that “this scenario makes you think about each step and how the questions relate to the problem.” Another student indicated that both episodes would help foster an understanding “but the first is the best because Clarissa ...[is] answering question[s] that are posed to her - which help[s] with br[e]aking the question down ...”

Although the majority of students indicated that they found the scenario demonstrating guided-inquiry effective, most students did not provide clear explanations for their answers. To get a better understanding of why students value questioning, as a method of instruction, interviews were conducted.

Student Interviews

Three students from the second semester calculus-based physics course were interviewed individually. The interview began with the students completing the survey described above and explaining their responses. Students were then asked about the use of questions as an instructional tool, circumstances in which they consider the use of questions to be appropriate and beneficial, and how often they encounter the questioning approach.

Analysis of the interviews was consistent with survey responses indicating that students value the questioning approach as being effective because it breaks things down. In explaining why she chose scenario one from the survey (the scenario that uses the questioning approach) as fostering a better understanding, one student said, “...it was more clear ...because one person is actually asking a question - the other person is answering...He said one thing. She said one thing ... sort of the way I would be thinking about it.”

Comments by the students also indicated that they appreciate the questioning approach because it helps them to build confidence. When asked what method of instruction he preferred, one student stated, “I would rather be asked the question ... because then I’m not just being fed the information. I’m actually coming up with it myself ... I will learn it better if I figure it out myself rather than just being told it.” In commenting on instructor use of questioning in the classroom another student stated, “[the instructor] would keep on asking questions ... I like that... because it helped me not become dependent on him ... Becoming independent helped me build confidence.”

The interviews also confirmed that the questioning approach does not just take place in the classroom during instructor-student interactions. One student stated that during group work, “if we’re not sure then we’ll question each other and see if we find a path ...” In commenting on his use of the questioning approach with peers, another student stated, “That’s what happens with me and my friend all the time.” The student goes on to say, “I use the question method more often than not because I find people retain it a lot longer ...”

The students interviewed also mentioned that the physics tutors use the questioning approach as well.

Subsequently, we interviewed tutors about their particular tutoring methods.

Physics Tutor Interviews

Two of the three physics tutors, from the Spring 2008 semester, were interviewed. Their comments revealed that they too value and employ the guided inquiry approach when working with others. In commenting on the teaching strategy that he uses, one of the tutors stated, "I think our job as tutors is to get them to come up with the answers themselves; so, they know it ... I think the best way to do that is to ask questions to sort of trigger the info. The way I see it ... they have all the tools, but they don't know how to use them ... it's my job to sort of help them learn how to use the tools that they have."

The other tutor interviewed said that she began using the guided-inquiry approach after she was advised to do so by another tutor. She stated, "I'm a new tutor ... I really didn't know how to [tutor] that's why I kept questioning a lot of people on how ... they do what they do ... He [the tutor quoted above] said the best thing to do is ask questions ... Once they told me [to] start asking questions, it kind of just came ... I asked them [students she tutored] questions that I ask myself ... it's like thinking out loud."

The interviews with the second semester physics students and the tutors show how the use of guided inquiry has become the accepted instructional approach among both faculty and students in the physics program at CSU. The wide-scale use of this approach is evidence for a particular resource our students have – the view that active learning and questioning is the best approach to fostering understanding. Although this approach is implicit in our instructional reform efforts, we can further capitalize on this particular resource.

INSTRUCTIONAL IMPLICATIONS

The use of questioning in the introductory classroom is a tool that can be used to establish effective collaboration because it forces students to attend to the ideas of their peers. Although we find the frequent use of questioning as students engage in activities, explicit instruction on this practice may increase the amount of effective collaboration and establish norms for productive discussion. Data from the videotapes, surveys, and interviews show that students at CSU are receptive to this teaching technique. Because of this, instruction may benefit from explicitly incorporating peer questioning opportunities into our existing active learning environment. Although the students we focused on in

this study worked extremely well as a group, we find that other groups do not function as well.

This paper is an attempt to identify and provide evidence for a particular resource that students at the urban, comprehensive university possess. Future work would involve employing some of these research tools with different populations of students at different universities and conducting comparison studies. In addition, we would like to give the survey instrument as both a pre and a post test to see the effect the reformed introductory physics class has on student views of learning. We have not isolated the extent to which these resources are developed as part of the class versus resources that our students possess before entering the reformed physics class. By giving this as a pre and post test we will be able to comment on this. It would also be interesting to evaluate the level of effective collaboration in laboratories that are not part of our instructional revisions and also reform laboratories that are being conducted at pilot sites for our project.

Often we hear about deficit models that are applied to the urban student – this preliminary study begins to establish a set of resources that the urban student possesses. A better understanding of these resources could then serve as a guide toward the development of more effective instructional techniques.

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