Student Interactions Leading to Learning and Transfer: A Participationist Perspective

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Abstract. At Florida International University we have been experimenting with a novel exam format. We have been giving our introductory physics students a group exam followed by an individual exam that contains transfer questions related to the group exam. The group exam requires students to work together on a difficult new problem. This format reflects one of our primary learning goals for our students: to be able to learn physics on their own. Videos of the group exam reveal that students are highly collaborative and engage in productive learning activities; such as, sense-making and constructing new representations. The question addressed in this paper is: Is students' participation in the group exam related to their ability to transfer their knowledge to the embedded questions? We present analysis that shows that students' ability to transfer their knowledge is related to how much they participate and more subtly, how they participate in sense-making and representational activities.

INTRODUCTION

In this paper we wish to explore students learning physics from the participationist perspective. From the participationist viewpoint, student learning is viewed in terms of how they transform their activities or processes, both individually and collectively as a group [1]. At Florida International University we teach an introductory calculus-based physics class to 30 – 40 students using the format of the Investigative Science Learning Environment (ISLE) [2]. Our physics class places a strong emphasis on student participation and transformation of participation at the personal, group, and whole-class levels [3] through a) multiple iterations of formative assessment [4], b) building group dynamics, instructor mediation, and group contracts, and c) practicing productive methods of whole-class participation through co-generative dialogue activities [5] such as CMPLE [6].

The participationist classroom can be seen as essentially one form of a community of practice [7]. Classroom participants (both students and instructors) are modeled as participants in a community of learners working together towards shared learning goals [8]. Lave and Wenger originally suggested that members of a community of practice begin their participation as legitimate peripheral participants, gradually moving to becoming central participants [7]. Bielaczyc and Collins [9] subsequently extended this idea to learning communities by suggesting that depending on the activity engaged in and their expertise and confidence, students in a learning community may vary their participation, moving from centrality to peripherality and vice versa. For example a student with exceptional emotional intelligence may become a central participant in defusing group tensions, but may become a peripheral participant in a projectile motion activity in which he/she has a weak understanding of the physics.

As discussed above, there has been a lot of theoretical development of the idea of the classroom as a community of learners, but less investigation of how those ideas play out in practice. A necessary precondition for understanding transformation of participation is to understand exactly how important is classroom participation for learning? It is generally believed that in a classroom such as ours, participation is the key to student learning. But what does this participation really look like? Can we identify central and peripheral participants? Does the nature of a student's participation matter for their learning?

In this paper we wish to address the following research questions: In what ways is student participation connected to their learning? Can we identify specific ways in which students participate or patterns of participation that support and aid their learning? For example, in a group of students engaged in sense-making, does it affect a student's learning if he/she takes on a leadership role in the activity versus passively listening to the conversations of others in the group?

METHODS AND MATERIALS

We decided to investigate our research questions by studying our students during their exams. For each exam, students first take a two-hour group exam, followed in a couple of days by a two-hour individual exam. In the

group exam we pose a problem for students that needs to be solved using physics they have not yet learned. For the example we consider in this paper, we posed two problems involving static friction acting in the direction of motion while previously, students had only encountered the most simple cases where static friction prevented a stationary object from moving. In the group exam, students are allowed to work together as a whole class to answer the questions. They are given unrestricted access to all resources at their disposal including a collection of different textbooks and the internet, as well as equipment that can be used to build models and conduct testing experiments. Students are expected to hand in one write-up per group of 3 for grading. They are graded on how well they explain and justify their reasoning to prove that they understand the physical scenario they are investigating. Students are also informed that there will be one or more questions embedded in the individual exam which will specifically test what they learned during the group exam. Those questions are carefully designed to see if the students can transfer and apply what they learned in the group exam to a new situation.

The group exam provides us with an ideal opportunity to study how students interact with each other and how they participate in learning activities without interference from instructors. The accompanying individual exam allows us to measure what they learned and transferred from the group exam. For this paper we studied one group exam and accompanying individual exam — the first mid-term. The group exam was recorded using video cameras from 4 different points of view. The goal was to record students' interactions. The camera operators were instructed to remain at a specific table, but follow students who left the table to make contact with students at other tables. In this way we aimed to construct a picture of how the class was collaborating as a whole

The group and individual exams

Group Exam. 1. a) When you start walking, the frictional force exerted by the carpet on your shoes is static or kinetic? Which direction does it point when you transition from standing still to moving forwards? Clearly explain your answer with proper diagram(s). b) Imagine Professor Brookes is pedaling his bicycle from a standstill, going faster and faster (i.e., he's speeding up). Consider him and his bicycle as a system. I) Compare the magnitude and direction of the frictional force exerted by the road on, i) the back wheel of the bicycle, ii) the front wheel of the bicycle. II) Explain what object is exerting an unbalanced force that allows him to accelerate.

2. In the picture below, a person is pulling a 3-box system with a rope attached to box 2. The rope is horizontal.

Box 1 has a mass of 1 kg, box 2 has a mass of 2 kg, box 3 has a mass of 3 kg. The coefficient of static friction between box 1 and 2, and between box 2 and 3 is $\mu_s = 0.5$. The coefficient of kinetic friction between the floor and box 3 is $\mu_k = 0.1$. If we assume the system is already accelerating to the right (i.e., it is already sliding), what is the maximum acceleration of the system and maximum force that the person can exert on the rope without boxes slipping off each other? (i.e., box 1 should not slip relative to box 2, and box 2 should not slip relative to box 3.)
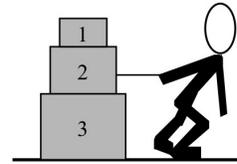
Individual exam, transfer questions. 1. A crate sits on the flatbed of a truck that moves towards the right ($+x$ direction) with increasing speed. The crate does not slide but instead moves to the right with the truck. A friend draws the force diagram for the crate. (Shown in the figure.) What things are wrong with this force diagram? Explain your reasoning. Provide an improved force diagram for your friend.
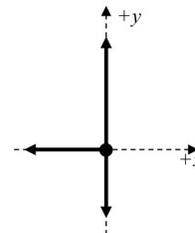
2. A horse is urged to pull a wagon. The horse refuses to try citing Newton's third law as defense: The pull of the horse on the wagon is equal but opposite to the pull of the wagon on the horse. "If I can never exert a greater force on the wagon than it exerts on me, how can I ever start the wagon moving?" asks the horse. How would you reply to expose the flaw in the horse's argument and convince the horse to pull the wagon (using physics reasoning of course)?

Note that these are not the only two questions on the individual exams, but are the two questions that were embedded measure what students learned from their group exam. While question 2 is common to most physics textbooks, we believe the majority of our students had not seen this question before since most had never had a physics course in high school and there was no assigned textbook for the class.

Grading rubrics for transfer questions

We devised the following two rubrics specifically targeted to look for transfer from the group exam to the two individual exam questions above:

TABLE 1. Rubric for individual exam question 1

Any mention of friction	+1
Mentions static friction only	+1
Friction points in $+x$ direction	+1
Unbalanced force in $+x$ direction	+1
No other forces in x direction	+1

TABLE 2. Rubric for individual exam question 2

Any mention of friction	+1
Mentions static friction only	+1
Different forces acting on horse and wagon	+2
Unbalanced force in direction of motion	+1

RESULTS AND ANALYSIS

Group exam

Studying the video footage of the group exam, we identified 5 key collaborative learning activities that students engaged in when they interacted with each other. These were:

1. Sense-making: Students discuss the material with each other in order to make sense of the physical scenario presented to them.

2. Co-representing: Students work together to draw diagrams, charts, models, etc. with material readily available to them to help each other understand the problems.

3. Teaching: Students explain the material to each other to the best of their knowledge as well as perform experiments to demonstrate a key idea.

4. Questioning: The students question each other's understanding of the material. This may arise when a student does not understand what another is explaining.

5. Checking: Students compare each other's answers or a student checks his/her answer with another to see if they are in the right track or not.

The theoretical perspective and research questions discussed in the introduction naturally lend themselves to social network analysis which, amongst many other things, can be used to quantify the centrality of actors in the network (in our case, students) in terms of their connectedness to other actors (students), and additionally the direction of those connections.

One researcher coded all the footage from the four cameras according to the following procedures: The researcher first identified episodes of interaction between two or more students. When a group of students engaged in one of the activities described above, then they would receive a code corresponding to that behavior. Care was taken to identify the initiator(s) and recipient(s) during any interaction episode. These interactions were recorded in a matrix format with the rows of the matrix representing the initiators of the interactions while recipients are in the columns. Each interaction was given a numerical value of 1, and the total number of interactions between students was quantified in this manner. Consider the following example: Three students, A, B, and C engage in a co-representing activity. A and B both hold whiteboard markers in their hands and both make contributions to the diagram they are drawing on a whiteboard while student C watches them without talking or contributing to the diagram. In this case A and B are both initiators *and* recipients in the activity while C is only a receiver. The matrix and corresponding network diagram are shown in Fig. 1 Using this method we were able
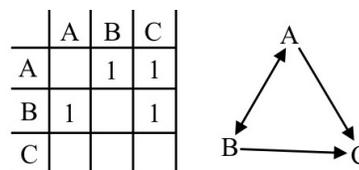

FIGURE 1. Co-representing network for students A, B, and C.

to construct a social network for the 2-hour group exam period, for 3 of the 5 activities described above (sense-making, co-representing, and teaching). The other two activities (questioning and checking) happened so infrequently that we were unable to construct a viable network.

We decided to use *degree* to quantify a student's connectedness within the network. In social network analysis an actor's (student's) degree is related to how many connections they made. Social network analysis software, UCINet, was used to calculate each student's degree in the three activities (sense-making, co-representing, and teaching). Degree was further subdivided into *in* and *out* degree, where *out degree* meant a student was initiating or guiding an activity, and an *in degree* meant a student was a receiver of information in an activity.

Grading the exam transfer questions. Two researchers graded students' responses based upon the two rubrics given above. On Question 1, the grades given to the students were in 94% agreement amongst the researchers and 71% for Question 2. After the researchers discussed the grades given to the students with

each other, they were both in 100% agreement for both questions. The grades the students received on the transfer questions were plotted against their corresponding in and out degree values to determine how a student's participation in the classroom affects their performance. The resulting correlation coefficients are presented in Table 3

TABLE 3. Correlations between exam questions measuring transfer (question 1 and 2) and other exam questions unrelated to friction compared against student participation in three productive learning activities during the group exam. "out" = out degree which measures students' connectedness in initiating (leading) an interaction and "in" = in degree which measures students' connectedness as receivers in learning activities

Activity	Correlation r for questions 1 & 2	Correlation r for all questions not involving friction
Sense-making (out)	0.43*	0.37*
Co-representing (out)	0.34*	0.38*
Teaching (out)	0.39*	0.35*
Sense-making (in)	0.34*	0.08
Co-representing (in)	0.17	0.04
Teaching (in)	0.31	-0.15

* correlation significant at $p < 0.05$ level (two-tailed t-test)

DISCUSSION AND CONCLUSION

There are a number of interesting implications that we can observe from these results. First of all, as expected, one's degree of centrality or peripherality in different productive learning activities correlates moderately well with performance on transfer questions in the individual exam. Second, it is better to be an active rather than passive participant in those productive activities. This is supported by the result that in degree is a much poorer predictor of exam performance. In fact, only in the sense-making network is there a significant correlation between passive participation and transfer. In summary, it appears that it is better to give than to receive.

More interestingly, we wondered if student participation was predictive of transfer, or could it simply be the case that being a more successful student would mean that such a student would be more confident and therefore be more prone to engage centrally in productive learning activities because of that confidence? The correlation between student participation and performance on other exam questions that have nothing to do with friction suggest that we cannot make definitive statements either way. It is likely that interaction between learning and participation is a self-reinforcing bidirectional one. Success in classroom assessments builds confidence and leads to more central participation in learning activities; and better participation leads to great learning, more success on assessments and this results in higher levels of confidence. This would be an example of a positive feed-back loop, a concept we have mentioned in earlier work on classroom dynamics [3].

A possibility for future research would be to follow the participation of individual students longitudinally through the course of the semester. If the participationist framework is correct, we should expect to see students who measurably (by social network analysis) transform their participation through the semester and undergo a corresponding improvement in learning as measured by transfer questions in the individual exams. In future work we could also consider how the students in the classroom connect to a broader network of external resources such as textbooks and internet webpages.

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