

Designing a physics learning environment: A holistic approach

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Abstract. Physics students enter our classroom with significant learning experiences and learning goals that are just as important as their prior knowledge. Consequently, they have expectations about how they should be taught. The instructor enters the same classroom and presents the students with materials and assessments that he/she believes reflect his/her learning goals for the students. When students encounter a reformed physics class, there is often a “misalignment” between students’ perceptions, and learning goals the instructor designed for the students. We want to propose that alignment can be achieved in a reformed physics class by taking a holistic view of the classroom. In other words, it is not just about teaching physics, but a problem of social engineering. We will discuss how we applied this social engineering idea on multiple scales (individual students, groups, and the whole class) to achieve alignment between students’ expectations and the instructor’s learning goals.

Keywords: Physics education, learning environment, learning goals, attitudes, motivation

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INTRODUCTION

Many Research-Based Instructional Strategies (RBIS) in physics are initially successful when implemented by their developers, but other adopters sometimes struggle to achieve the same level of success. Firstly, students are resistant to reform [1]. Secondly, when physics instructors try implementing one or more RBIS, they quickly discover that they do not work as advertised [2]. The most frequent result is that the instructor drops the reform elements or severely modifies them [3].

It is not for lack of desire for change that this failure occurs. Students are acutely frustrated and turned off by traditional instruction in physics [4]. Likewise Henderson and Dancy [2] have documented that many physics instructors are dissatisfied with the current status quo and see the need for change in their classrooms. In summary, students want change, instructors want change, but successful dissemination of RBIS is not as widespread as we would hope.

In this paper, instead of examining one interaction or feedback at a time, we will consider taking a holistic approach to designing our physics class. Our approach has three components: 1) We tried to ensure that all course elements were structurally aligned. 2) We implemented an active program of “social engineering” that attempted to find common ground between students’ attitudes, beliefs, and expectations about learning; and the instructor’s learning goals for

his/her students. 3) We paid careful attention to designing the learning environment to maximize effective communication and interaction between students.

THEORY AND COURSE SETTING

Interacting System Model

We view the physics classroom as a multilevel complex dynamical system [5]. In particular, the physics classroom can be viewed as having scaling properties: The smallest scale is each individual student. The next level is a group of 3 students. The third level describes interactions between groups of students that are necessary for the class to function as a whole. (See Fig. 1.) Tobin [6], and Samuels & Brewster [7] both suggest that we no longer treat the problem as one of getting our students to change their beliefs about learning, but that we should foster student-student and student-instructor interactions to find common ground about shared beliefs about learning and learning goals.

Since multiple classroom elements interact with each other to form a complex web of interactions and feedbacks, we have to consider how all classroom elements work together as a whole. We attend to how all elements of the classroom align with each other to

send students a coherent message about their learning experience.

In the classroom, the cycle of learning involves observing, explaining, testing and revising. The instructors' role in this class is to construct the environment so that students use this learning cycle on each of these levels. Our focus is therefore on getting students to reflect on their learning [8] and productive interactions between individuals and groups [9].

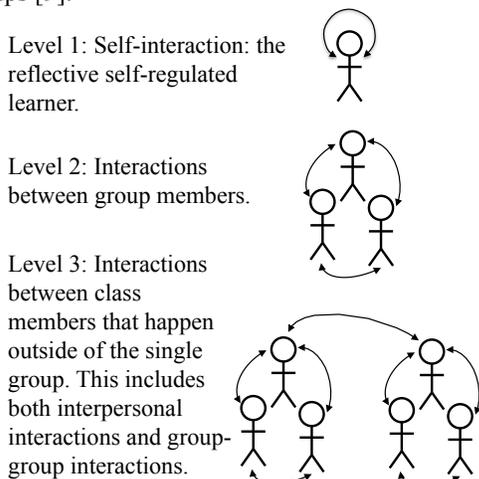


FIGURE 1: A three-level model of classroom interactions.

In Fig. 1, each level involves both reflection on learning and interactions between individuals and groups. On the individual level, each student practiced reflection through submitting a weekly journal and through written explanations in homework. In class, students work in groups of three on experiments and problems. They turned in work as a group, requiring intensive collaboration. As a class, students frequently engaged in whole-class discussions. These discussions involved not only reflection on what was learned, but a continual negotiation of meanings and representational norms in the classroom.

Curriculum and Structural Alignment

Before we attempted to implement any specific interventions or design specific aspects of the environment, we needed to ensure that class elements sent a unified epistemological message to our students. We call this concept “structural alignment.”

In our introductory calculus-based physics class of 30 students, we used the Investigative Science Learning Environment (ISLE) [10]. In ISLE students are expected to design their own experiments to observe physical phenomena, come up with patterns and multiple explanations to describe and explain the phenomena they observed, and design additional experiments to test and evaluate their explanations. In

addition, students are expected to develop scientific process abilities such as the ability to evaluate one’s assumptions, and to apply their knowledge to solve real-world problems.

If we step back and look at this physics class in its entirety, the key epistemological goal is this: In a year of introductory physics, students should move epistemologically from relying on authoritarian external sources of knowledge to self-reliance or “self-authorship.” [11] In other words, they are expected to develop the ability to evaluate sources of knowledge, using the best information available, and the epistemic tools of physics.

We propose that the first step to successful implementation of RBIS is to ensure that all elements of the course are aligned with the bigger picture. We adapted and adopted RBIS on the basis of whether they would support students’ trajectory from relying on external authority to “self-authorship.” We present one example in detail below.

With regards to textbooks, we got rid of the assigned textbook. Students were made aware of a class library of about 20 different introductory physics textbooks (both calculus and algebra-based). They were free to borrow these books during class time or take one home for a period of time.

In many instructional strategies in physics the instructor is expected to function as a guide who does not provide “right” answers, but scaffolds student reasoning. If that is the case, do we try to “ease” the students into a different mind-set by giving them a textbook so they don’t feel lost by the lack of definitive answers coming from the instructor? The structural alignment perspective guided us to do exactly the opposite. If we as instructors are not going to give students the right answers, but at the same time give them a single textbook with the “right” answers, we are sending two different messages to the students. These messages are in epistemological conflict with each other.

As a result of all the changes such as the one described above, the problem that we faced was that firstly, students felt confused by and afraid of the strange situation they found themselves in: “...*I said, what is this? I got to do my own thing? I’ve got to actually think on my own?*” (Jeremy). Secondly, students didn’t trust each other to learn. They wanted to talk directly to the instructor who they saw as the source of “correct” knowledge. The fear was that working in groups doing inquiry learning was tantamount to “*the blind leading the blind*” (Estelle, personal communication.)

Below we will describe class activities and structural elements that we implemented to help students feel more comfortable and to help instructors and students to find common ground with each other

and with themselves about their attitudes towards and beliefs about learning in a physics class.

Activities

We implemented the following class activities to foster student-student and student-instructor communication.

Marshmallow challenge [12] Goal: Foster productive interaction between group members. Help groups think about a) working under pressure, b) dealing with ill-defined tasks, c) sharing responsibility, d) negotiating power structures. Class time: 0.6 hours. Implemented: First day of class.

Four-color universe [13] Goal: Encourage inter-group interactions and sharing of ideas and knowledge. Class time: 1 hour. Homework time: 1-5 hours. Implemented: Week 1.

Learning Analogy [14] Goal: Have students reflect on areas of their lives in which they are expert learners. Build a common shared model of what learning and understanding mean. Class time: 1.5 hours. Implemented: Week 2.

CMPLE [7] Goal: Foster individual student reflection on how they learn. Build community, sense of shared identity and common goals. Promote joint ownership (instructor and students) of the learning process. Class time: 1 hour. Homework time 0.5 hours. Implemented: Week 3.

Curriculum Structural Elements

Journals Goal: Fostering self-reflection and individual student-instructor interactions.

Every student kept a weekly journal structured around three repeating questions; see [15].

Writing emphasis Goal: Foster self-reflection and communication on all 3 levels.

We placed special emphasis on student writing in homework and exams. Students were required to explain in words every step of their reasoning process. This was in addition to solving the problem and showing their calculations.

Group Contracts [16] Goal: Allow students to take responsibility for the functioning of their group.

Tables Goal: Support group and whole-class interactions.

Tables were structured so that groups of 3 could easily cluster around a single whiteboard or single laptop. Tables were small enough to allow easy group-group communication and overall layout promoted the free-flow of information from table to table [17].

Whiteboards and circle discussions [18] Goal: Build student-centered classroom, communication of

representational norms, foster communication throughout the classroom.

Online discussion board Goal: Promote interpersonal interactions.

Students were encouraged to use the discussion board to share any videos related to the class, share ideas, ask each other questions about homework. Plan exam reviews, or simply arrange meet-up times to study.

In-class review Goal: Promote student-student and instructor-student communication.

Each class started with a review of what was learned in the previous class. The review was entirely led by students. The review was a critical place where students could share what they had understood and were still struggling with. This, in turn, guided how the instructors approached the rest of the class time.

Group activities Goal: Create inter-dependence between group members and inter-dependence between groups.

Group activities especially designed to foster personal interdependence between group members were the design labs and group lab reports. Design labs are sufficiently difficult that no single group member can perform the experiments and analysis on their own.

Group exams required the entire class to learn something new or transfer what they had learned to a very novel situation. These tasks were sufficiently difficult that no single group could complete the task on their own.

ANALYSIS

Each year, for two years of implementation, we conducted interviews with about half of the students at the end of the second semester. In addition we collected students' weekly journals. These two sources suggest that our explicit interventions helped students to feel more comfortable with the class structure and changed their attitudes towards learning physics.

In an interview, Jeremy (a pre-med going into optometry) offered us an example of the typical change in attitudes that we observed in students who took the class:

When I first came in I had no idea what to expect...I'm so used to traditional teaching and have a professor read it to you and explain it to you. And I said, what is this? I got to do my own thing? I've got to actually think on my own?

And in the end I decided that this was probably the greatest class that I'd ever taken only because I learned so much. Had I taken physics in a regular class, like in a regular, I know I would not have learned as

much as I learned...because I studied physics also when reviewing for my OAT, and to be honest with you I didn't have to study for it because I knew everything...you learn it so well the first time that you never forget it...

Daniel described his experience of the class in the following way:

The setting in the physics classroom is so comfortable and I just like being in it so it's more motivating to go study... If I have a problem, everyone's going to help me. Everyone's having the same issues, and everyone's at the same level, we're all going together – it really didn't feel like studying to me...it's such a surprising thing. I've never really felt that before.

Daniel's description contains many of the elements we were trying to achieve in creating a whole-class community.

Generally starting the semester with group work activities that are seemingly unrelated to physics may engender student resistance. However, from students' weekly journals, we discovered that they learned a great deal from the activities:

The four-color-universe activity really helped to show me how important teamwork is because the activity could not be done by one person – Nell

This week I learned how to work in groups to accomplish a common goal. This made [it] easier to learn new material with the influence and communication with people attempting to achieve the same wish. – Liz

It is extremely important that when there is a group of people working together they communicate with one another and work as a whole. If each person were to work individually, no goals would be accomplished...trying to figure out the colors of the universe, the entire class has to listen to what other groups have observed and learned. This allows for a greater result. – Arlene

These examples suggest that students got the underlying message that these activities were trying to send.

CONCLUSION

We have presented a view of the classroom as a complex dynamical system. We attempted to attend to all class elements in a holistic way, thinking about how each element supported all the others.

Future research should examine whether other instructors can successfully adopt and implement these strategies.

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