

# **Bridging Critical Points: discontinuities in high school and university physics education**

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The paper examines data collected from teaching an introductory college physics class offered at a public high school. Assessment of student achievement demonstrates that students are able to perform at a college level. Nonetheless this achievement is not recognized by the institutions supporting this experimental course. Analysis of detailed daily notes begins to answer why and how students are marginalized in this educational system. Particularly, three themes of structural, normative and epistemological discontinuity detail why these students or institutions fail.

## **Introduction:**

While most students in the United States graduate from high school, they generally do not graduate from college. According to a recent study by the Stanford University Bridge Project, approximately 90% of White students graduate from high school, 70% enter college, and less than 30% of this population graduates with a Bachelor's degree.[1] The attrition is yet worse for African-American and Latino students. There is an educational gap between high school preparation and college success. The authors of the Bridge Project make several policy recommendations to address this gap. They advocate, "[1] senior-year courses ... linked to postsecondary general education courses [and, 2] expanding successful dual or concurrent enrollment programs between high schools and colleges so that they include all students." Simultaneously, the California Master Plan for Education cites the importance of a bridge between high school and university [2]. In particular, the two-year college system plays a critical role by providing "opportunities for high school seniors to enroll concurrently to further strengthen their readiness for college or university enrollment and to accelerate their progress toward earning collegiate certificates or degrees."

In the Fall semester of 2002, I undertook a study to examine the practicalities of offering a university level physics course inside a high school. (A more detailed description of the class, motives and structure can be found in [3].) The experimental high school course was designed to mimic the University of California's introductory

algebra-based physics sequence while simultaneously offering high school students one semester of community college credit. The class was a three-way partnership between the university (where I was housed), the high school (where the class was taught) and a local community college (which would provide credit and other future courses for the students).

The following paper examines student success and how student achievement is bound to a broader framework – coordination among different institutional partners, and reconciliation of their differing cultural norms. Ultimately, significant student achievement is substantively diminished by the surrounding institutional cultures. This design experiment [4] examines discontinuities in the structures, norms, and epistemology of partners begins to answer why and how students are marginalized in this educational system and why these students, institutions, or both fail.

## **The Study:**

The class was held at a public charter school located in a large California city. The high school itself was diverse (representative of the city demographics), progressive, project-based, relatively new, and small (approximately 400 students). Students were admitted by lottery after a pre-screening application that selected for motivated, rather than high performing students. The class met three days per week and was comprised of three lectures and one recitation section. We followed a traditional text, and used a hybrid of lecture notes and activities from UC Physics 1 and University of Maryland Physics

121. The recitation sections were largely based on *Tutorials in Physics* [5]. The class began with 38 students and ended with 31. Student background varied from those who had taken no physics and had mastered limited amounts of trigonometry to students who had taken an advanced placement physics course and were concurrently enrolled in a college level calculus class.

Two forms of data were collected: quantitative assessments of student mastery of the domain and qualitative field-notes. At the beginning and end of term, students were issued the Force Concept Inventory (FCI) [6]. During the twelfth week of term, students were issued the same mid term examination as was issued the prior year at the University of Maryland. In addition to using identical exams, the University of Maryland scoring rubric was used to grade the exams. Lastly, approximately 60% of the class opted to take an external final exam developed and administered by the community college system. Within 24 hours of teaching each class, I wrote a detailed account of the day's activities. While these data may be considered subjective, they serve to interpret the meaning of the "more objective" and quantitative measures. Analysis of these notes helps interpret why and how this course evolves as it does by identifying critical structures, norms, practices, and beliefs of the individuals and participating institutions.

### **Results / Discussion:**

Over the course of the term, it became clear to me that this group of high school students could learn college level material. The high school course average on the Maryland mid-term was 68%; the Maryland students averaged 62%. On the pre- and post- conceptual survey (FCI), students posted gains of 44%. During the same term, students in one of the most progressive-introductory physics courses at the University of California posted the highest measured gains at the institution: 23%. (Both the high school and the university course pre-test averages were 48%.) These assessments were corroborated by a myriad of examples from daily field-notes. A not remarkably unusual example of student mastery appears in day 43 of these notes:

*As I was grading the homework... [For] a standard, but complicated problem using*

*Bernoulli's equation, Larry spent a page and half working from the basic equations that I had provided in class. In the end, he gets the right answer,  $v=\sqrt{2gh}$  and recognizes this is the same for free fall. He writes, "OKAY! I now realize this is the same as  $v=\sqrt{2gh}$ . The book says as with Torricelli [a theorem I had not mentioned in class] That if  $P_3=P_1$  then  $v=\sqrt{2gh}$  and this is really what I just derived."*

Despite coordinating the course outline and syllabus with each of the partnering institutions from the outset, late in the term of the course, it was determined that if students wanted to receive college credit for their efforts, they would be required to take a challenge exam at the community college. The exam was created for the students by the faculty of the community college. If students opted to take the challenge exam, they would receive a college transcript with the grade they received on the exam (including D or F). At the end of the course, 19 of the high school students opted to take the exam. Of the 19 students, 17 were the top-performers (A or B) in the high school class. On the community college exam, students scored as follows: 1 A, 3 B's, 7 C's, 1 D and 7 F's. In short, this evaluation is well below the level of mastery demonstrated elsewhere. Notably this external exam differed from those exams issued as part of the course.

While considered a success within the confines of the classroom walls, this micro-culture sits within broader, existing worlds to which it is structurally bound. From that vantage point it may be seen as a failure of the students (to succeed in the established cultures), or of the institutions (to support the educational and social development of students). Three emergent themes from the daily notes begin to detail why so many students failed the community college exam, and why it is such a challenge to create sustainable and scalable forms of inter-institutional collaboration.

### **Structural discontinuity:**

These systems are not designed to coordinate on joint activity. Arguably, the high school is intended to hand students off to the university system; though, the statistics presented in the introduction would suggest even this might not be the case. Nonetheless, a variety of organizational and structural issues presented fundamental

obstacles to the success of a sustained collaborative venture. Most notably, initially, I was not allowed to teach in standard public school. While I teach current and future high school teachers, I am not certified to teach high school students. A charter school allowed me to teach without certification.

Further structural discontinuities arose over the use of available resources. As I observed during the first day of teaching:

*For as little as UC pays attention to / cares about introductory level physics., [THE HIGH SCHOOL] PROVIDES FEWER RESOURCES THAN U.C. WHEN IT COMES TO EDUCATING STUDENTS in physics... So I'm in charge of ... 40 seniors. I'm supposed to cover 16 weeks of physics which will be the equivalent of [algebra-based] Physics at UC. They will not be running a lab. I had to talk the administration into offering recitation sections. [Although] they had told me they'd offer one five days per week, in fact, they are only offering 3 [later, reduced to 1]. They have no equipment for demonstrations. I have no TA's, no graders, no proctors, no demonstration staff and no grad students. Just me, 40 students, a lousy textbook, and a [digital] projector*

Similar structural discontinuity may be observed in the time allotted for supporting and paying teachers. As I noted, at the high school:

*I get paid for face-time with the kids. Now I'm an hourly [employee] where they wanted to pay me for 6 hours (3 hours lecture, 3 recitation).*

In the high school culture, 5-6 hours per day is spent teaching. A full time teaching load is 25-35 contact hours per week. In the university system, a full time instructor is expected to spend 12-18 contact hours per week, often less.

A variety of other, more mundane and daily structural issues challenged our abilities to coordinate. The choice of textbook was set by the high school (in order to save students / school money) rather than by the university demands, or the choice of the instructor. Discontinuities of institutional schedules prevented other forms of coordination, such as bringing university students to participate in the high school environment.

Each partner institution had its own structure that constrained how the class could operate. At many times, the differing institutional structures were at odds. Most notably, in the end, the arrangement of

institutional structures required the high school students had to take an externally developed, high-stakes exam in order to receive college credit.

#### Norms and practices:

These surrounding and sometimes conflicting institutional structures are instantiated in differing norms and practices. For instance, university instructors generally act autonomously, and cover a curriculum of their choosing (bound by history, a text, and loose curriculum guidelines). If university instructors wish to make a class interactive, progressive or even include an emphasis on developing student epistemology they are free (and occasionally encouraged) to do so. Instead, the high school turned down my offer to have an entirely interactive class, requesting that I offer straightforward lectures:

*I'm being asked to teach a straightforward lecture class. Somehow the high school has this vision of University courses which is based on the LEAST optimal college environment rather than the MOST optimal. Funny. I only agreed to lecture if I can have recitation sessions every day. Now they have them 3x / week [later reduced to 1]. I told [the vice principal] that while this is known to be a sub-optimal learning environment (lecture), I suppose it could prepare students for the rotten education they would get at UC if they got in. [The VP] laughed and said, "yeah, I guess we've sold our soul to the devil here."*

While high school instructors may have some autonomy in the classroom, curriculum standards, external assessments and certification constrain the scope of instruction and approach. In a high school, it is often mandated that external examiners evaluate a class. In the university setting, it is remarkably rare..

#### Ideology / epistemology:

These differing norms and practices reflect differing ideological and epistemological commitments. Least obvious, but perhaps the most critical set of discontinuities within this system are the norms (or epistemological commitments) of what it means to learn physics. If the high school, community college, and university were aligned in terms of what it meant to learn physics, many of the structural and normative differences would have disappeared. It would not have mattered that students had to take

an exam, or that the course occurred in largely passive mode. In light of the community college exam, had we considered physics to be a purely procedural domain of inquiry where formulae are manipulated to calculate answers in the back of a textbook, there may not have been a problem. However, this high school class was directed by a differing ideology. As stated in the syllabus:

*This class is not going to be like traditional science classes where you are expected to memorize a bunch of facts. It will be better, and with your genuine effort, more fun. We will focus on developing skills to think rationally (and coherently) about the physical world. We will pay attention to results ("answers"), but more importantly how we get the results and whether or not these results make sense (are they valid and how do they sit with your intuitions, which can help or hinder the process). Developing the skills to think scientifically is the goal that we are aiming for.*

Apparently students themselves became aware of the difference between this approach and that of the community college. On day 36, I note:

*Marcia wanted to know if [our mid-term] exam was going to be like ...the [community college] mid-term that I had assigned [previously for] homework. Steve answered for me--- no it will be more about problem solving and reasoning.*

As evidenced by traditional practices in the high school and community college system, the nature of the challenge-exam, mastery of physics was more closely aligned with mastering procedures and short, analytical problems that emphasized the manipulation of formulae. As described, the experimental course strived to include a broader framework for such procedural and problem solving strategies, which included synthesis, estimation, reflection, articulation, sense-making, and conceptual mastery. The students' ultimate failure on the community college exam reflected this misalignment.

A final comment by one of the collaborating faculty members at the community college identifies a final, and important area of discontinuity-- that of agency. Who is responsible for the students failing the final exam? He notes:

*If students don't learn that there are consequences to their actions, we will not be giving them the education they deserve and need.*

### **Conclusions:**

While there are clear calls to couple better secondary and post-secondary education in the United States, we lack a theory and detailed understanding of how to do so in a sustainable and scalable fashion. The present study begins to document fundamental discontinuities that are rooted in the structures, norms, and practices of high school and post-secondary education that must be addressed if we are to improve coordination within the educational system. While high school students are able to achieve high levels of success in a university-level physics course, these and other fundamental discontinuities mute the achievement of the students and seriously hamper efforts to create sustainable and scalable forms of educational collaboration. Alternatively, if, as other papers in the collection suggest, the educational system is designed to keep students from thinking critically and prevent them from continuing through the educational system, then it is achieving its goal. Finally, the observed discontinuities insure that change will not come easily. However, if we do seek change, in the long run, sustained educational reform requires restructuring -- simultaneously top-down (institutional structures and norms) and bottom-up (educational practices/ cultures).

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