TEACHING UNDERGRADUATE COURSES ON ROBOTICS AND CONTROL IN PRISON

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Why college in prison? There is growing public consensus that the system of mass incarceration in the United States needs reform. More than 2.2 million residents (0.73%) of the United States were held in state or federal prisons or in local jails at the end of year 2010 [1]. This incarceration rate is the highest in the world, and disproportionately affects racial and ethnic minorities: 4.35% of black males were held in custody compared to 0.68% of white males in 2010 [2].

Whether your entry point is through social movements like Black Lives Matter and Occupy Wall Street or through popular bestsellers like *The New Jim Crow* [3], chances are good that you have seen statistics like these and recognize that something needs to change. What is exciting for those of us with careers in education is that teaching is one way to have a direct positive impact on this problem.

The Education Justice Project [4] at the University of Illinois at Urbana-Champaign is one example of a growing number of programs nationwide that provide opportunities for higher education in prison and that welcome contributions from teachers in engineering and science, areas of study to which incarcerated men and women have had particularly little access. The mission of the Education Justice Project (EJP) is to build a model college-in-prison program that demonstrates the positive impacts of higher education upon incarcerated people, their

families, the communities from which they come, the host institution, and society as a whole. A short video is available that provides a good introduction to this program and its goals [5].

As its flagship project, EJP offers upper-division undergraduate courses to men incarcerated at the Danville Correctional Center (DCC), a state prison located in east-central Illinois. These men are enrolled in and receive credit from the University of Illinois. The courses are the same, and are often taught by the same people, as those offered to undergraduate students on the Urbana-Champaign campus.

Providing higher education to the incarcerated population has well-established benefits. For example, among prison-based interventions, it is the most effective way to lower recidivism (i.e., re-arrest, re-offense, and re-incarceration) and so produce safer communities and less government spending on prisons. Strikingly, it also impacts the *children* of incarcerated men and women. When parents are provided higher education in prison, their children—*outside of prison*—are more likely to attend college.

In what follows, I will describe my own experience teaching two engineering courses—one on robotics, one on control systems—to students incarcerated at DCC, as a member of EJP. I will begin by giving you a sense of the prison environment, focusing on my routine as an instructor and on the challenges faced by both instructors and students. I will proceed to describe the two courses, highlighting any differences between how I taught them at Urbana-Champaign and at DCC. I will conclude by reflecting briefly on what I value about teaching in a prison.

A note about language. Things at the main university campus in Urbana-Champaign are "on campus," while things at the Danville Correctional Center are "in prison" or "at DCC." The men in prison at DCC are "students at DCC," "EJP students," or "incarcerated men."

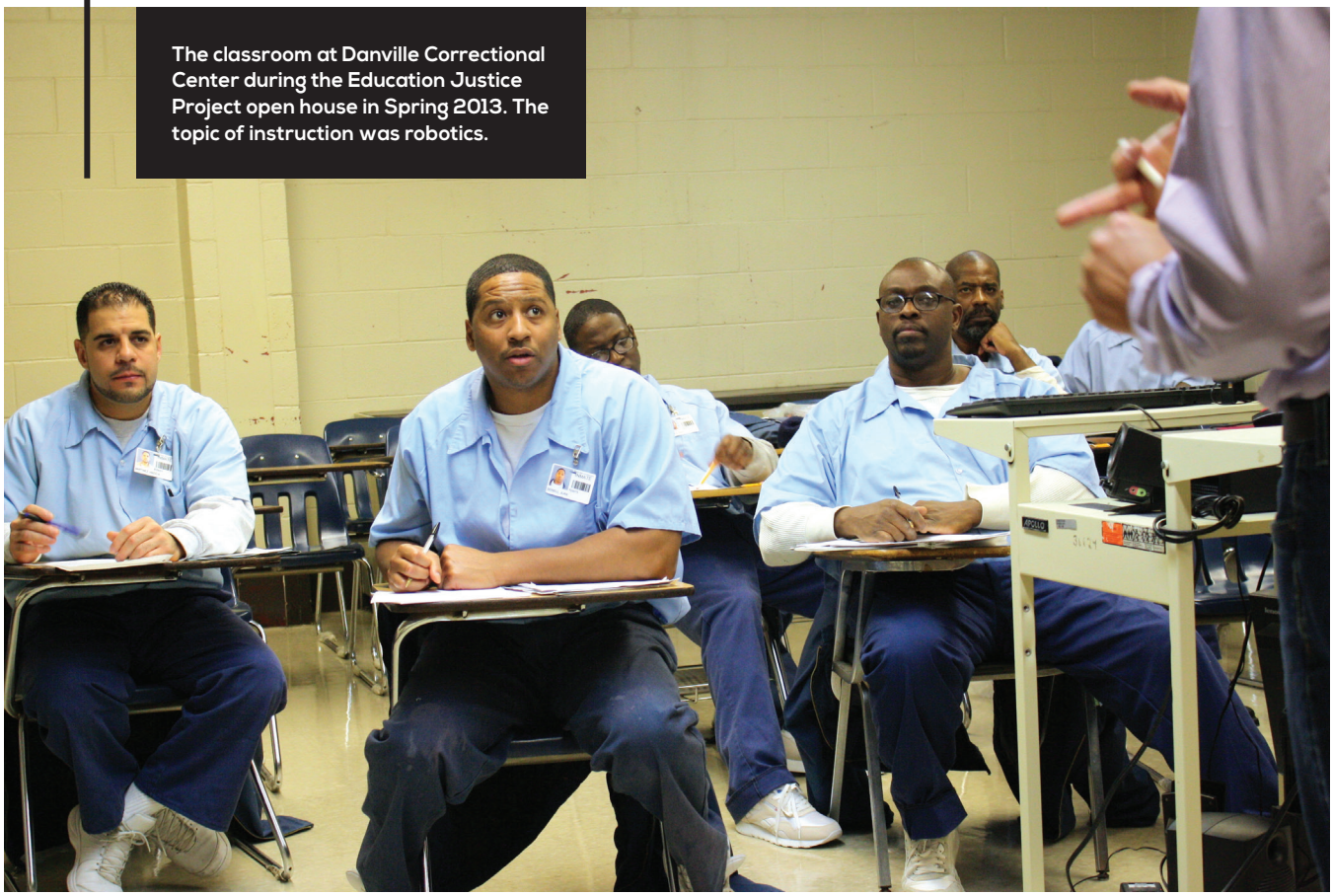
THE PRISON ENVIRONMENT AND WHAT IT IS LIKE TO TEACH THERE

During the two semesters in which I taught, Spring 2013 and Spring 2016, for-credit courses at DCC met once per week for three hours, 5-8 p.m., on Friday evening.

Each week had a routine. I joined other instructors at the Common Ground Food Co-Op, a local grocery store in Urbana, where we shared a car and drove out together at 3:45 p.m. We arrived at DCC, on the east side of Danville, at 4:30 p.m. Entering DCC, we presented identification to the correctional officer on duty. The officer checked that our clothes satisfied the DCC dress code, for example that we wore pants instead of shorts or skirts and shoes instead of sandals—modest attire. The officer also checked that we were carrying no prohibited items: cell phones, laptops, food, personal correspondence, pocket-knives, etc. We received our name tags and were ushered through several sets of locked doors that separate "outside" from "inside." Arriving next at an enclosed yard, we walked past other officers and often single-file lines of incarcerated men in transit from one building to another, for example from the dining hall to a cell block. We then entered the education building—which also housed a chapel and a gymnasium—and proceeded to the second floor where the EJP classrooms were located. Greeting the correctional officer on duty, we unlocked our respective classrooms—set up either with a round table or with desks and a chalkboard—and waited the few minutes for our students to arrive. I warmly greeted the students in my classroom by last name, "Mr. X" or "Mr. Y," as required by the DCC code of conduct, and they greeted me in turn as "Mr. Bretl." Physical contact was restricted to a handshake and small-talk was restricted to the topic of study. Instruction commenced, interrupted only by a ten-minute break at a time chosen by the correctional officer within the next three hours. A private, locked restroom was available to instructors during the break, with the incarcerated men using a separate facility. Sometime shortly before 8:00 p.m. we would hear the "time's up!" and students would quickly file out after another handshake. We followed more slowly, taking a minute to organize our rooms before making our way back across the prison yard, out through the gatehouse to turn in our name tags, and on to our car. The day ended as we arrived back in Urbana at about 9:00 p.m. and we returned to our own homes from there.

Disruptions were common.

Instructors might be denied entry to DCC if their name tag were missing from the gatehouse, if there were an issue with their clearance such as missing medical test results, or if they were "locked out" for violating DCC's code of conduct. Restrictions against fraternization with incarcerated men, in particular, prohibit behaviors that could be perceived as leading to social interaction. Sitting with one leg over the arm of a chair is an example of a behavior that could appear overly informal, be reported by a correctional officer, and lead to a lock-out. In most cases, instructors would not know if their entry would be denied until arriving at DCC, and so would simply have to drive home and try again the following week. Classes might be cancelled or delayed without warning if the prison were in "lock-down"—caused, perhaps, by a mis-count calling role in a cell block or by a change in the tower guard—during which all movement would be prohibited. Classes might end early, at the discretion of the correctional officer on duty in the education building. Individual students might be missing on any given Friday. All men require a "call pass" to leave their cell block, and this document might have been lost or mis-filed. Students might be held in "solitary" pending the resolution of a disciplinary incident. Students might also be removed



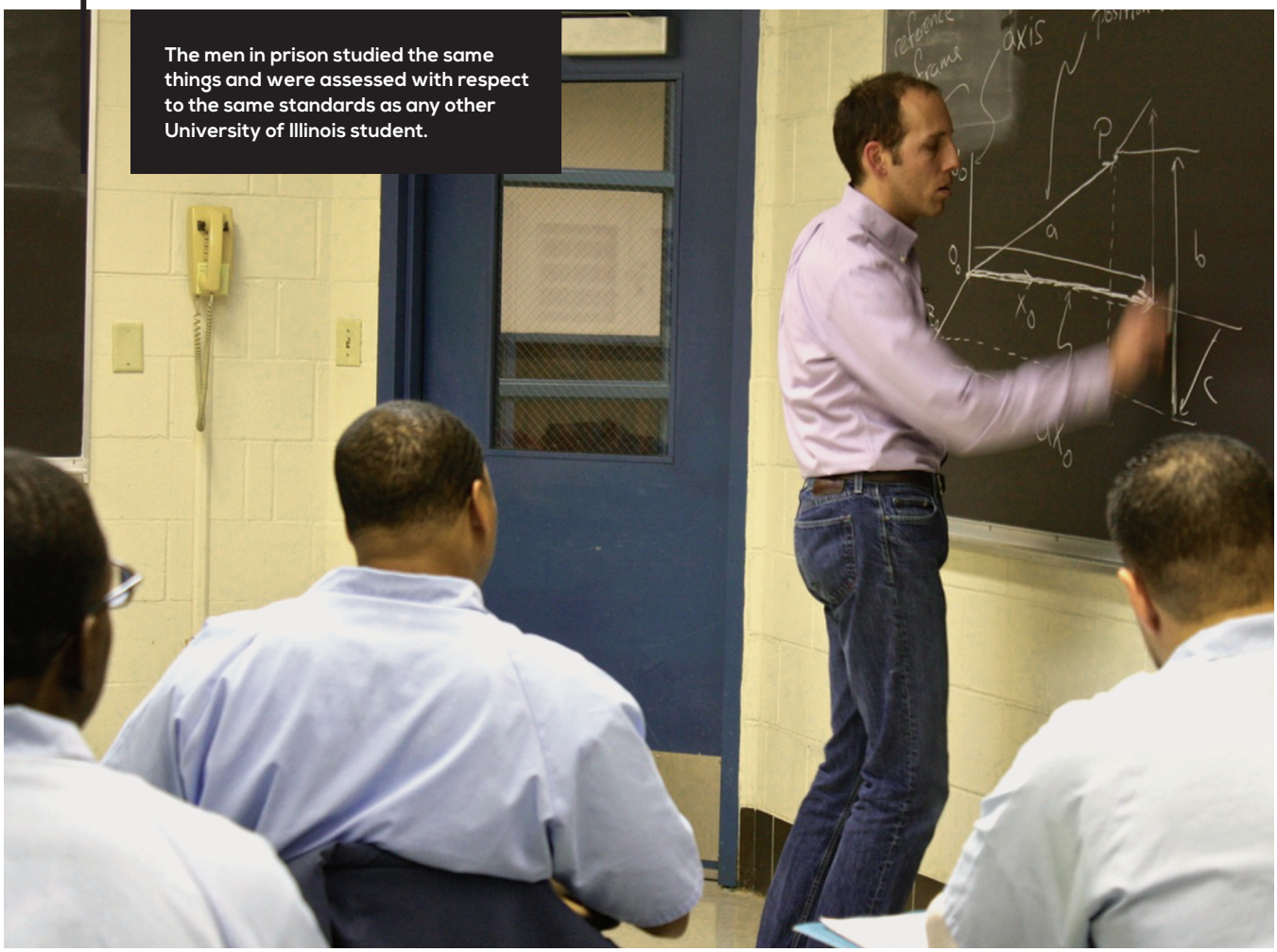
The classroom at Danville Correctional Center during the Education Justice Project open house in Spring 2013. The topic of instruction was robotics.

permanently from a course, either because they were released or because they were transferred to another correctional facility. Transfers, in particular, could happen at any time, without warning.

Common student practices were restricted in ways that they would not have been outside the prison.

Students could not communicate reliably with each other or with instructors outside of class time. Unsurprisingly, they did not have cell phones and could not send emails. It is less obvious how disruptive an inability to communicate easily with each other could be to their educational experience. Like all men incarcerated at DCC, students were assigned randomly to cell blocks and meal times and could not freely associate. Written correspondence was possible, but slow, so course materials—handouts, submitted work, feedback—were primarily exchanged in person during class time. Group work, as well, could only be done reliably during class time.

Students had limited access to standard educational resources. They had no internet: no online journals or databases to follow cross references, no search engines, no Wikipedia. There was a small community library in the education building, created and maintained by EJP, that held about 2,000 books. Some of these books were circulating and could be checked out by students and brought back to cells. Students could request other books from the University of Illinois library system. These requests could take weeks to fill through EJP and were then subject to clearance by correctional officers. Books could be rejected based on content or binding: for example, hard-backed books were not allowed in cells. Students could not search the university library catalog and so became aware of books to request only by cross reference or referral. There was a computer lab in the education building, also created and maintained by EJP, with fifteen terminals and a printer on a closed network. These terminals had software for word processing and spreadsheet creation, as well as other software like a python installation for programming. Students could ask for a call pass to enter the library and the computer lab outside of class during three-hour blocks of time. Most often, they would be granted no more than one three-hour block each week, so most students had no more than three hours access each week to a computer. Both the library and the computer lab were available only when a member of EJP staff was present, so staff and student schedules further restricted the times at which students could access these facilities. Some other supplies like graphing calculators were available in the



The men in prison studied the same things and were assessed with respect to the same standards as any other University of Illinois student.

education building and, at the discretion of correctional officers, could be taken to cells if required by certain courses.

Students had limited access to quiet spaces. Like all men incarcerated at DCC, their movement was restricted. When they were not at scheduled events—meals, exercise, chapel, class, job, visitation, etc.—students were in their cells. These cells were shared with at least one other person, who was likely not another EJP student and who may have had different views about TV use, conversation, etc.

Common instructor practices were also restricted.

Instructors could not easily hold weekly office hours, and so most provided office hours only once or twice during the semester. Each office hour would have to be scheduled in advance and call passes for students would have to be arranged. Each office hour would mean another visit to DCC, with the drive and the clearance process. It was unlikely that a single weekly office hour could be attended by everyone—like students at any college or university, students at DCC held part- or full-time jobs, at fixed times that varied widely.

Instructors could not freely share information with students. All course materials—written documents as well as audio and video recordings—were subject to inspection by correctional officers and could be denied entry, based on content. Policies for review varied. In 2013, routine handouts like notes, homework solutions, or relevant magazine and newspaper articles were given only a quick glance by officers at the gatehouse when entering the prison, and so could be used on the same day that they were inspected. In 2016, instructors were required to submit all course handouts to correctional officers no less than two weeks prior to their use, making it harder to be flexible and responsive to student needs.

Instructors could not easily conduct hardware demonstrations or laboratory experiments in class. Laboratory equipment that would normally be associated with engineering courses was, in general, prohibited.

It was never entirely clear what the boundaries were of these restrictions on students and instructors. Both rules and rule enforcement were largely discretionary, so we all engaged in some amount of self-censorship. If I had asked to bring a robot into the

prison, I might have raised concerns that caused correctional officers to look more closely at the content of my course, of other courses, and perhaps of the entire program. If I had distributed course material that pushed the boundary of what was acceptable, then I created risk that students to whom I gave the material would be punished or transferred to another facility.

Finally, it is important to acknowledge obvious demographic differences between students on campus and students at DCC. For example, of the students on campus, most are about 20 years old, few are people of color, and about half are women. Of the students at DCC, most are much older, most are people of color, and none are women.

TEACHING A UNIVERSITY COURSE ON ROBOTICS IN PRISON

I taught "ECE470: Introduction to Robotics" in Spring 2013 to 13 students enrolled at DCC. Twelve of these students completed the course with a passing grade and received university credit. One student dropped the course. The grade distribution was the same as would typically be seen on campus, where I had taught this course twice before to enrollments of primarily fourth-year undergraduate and first-year graduate students.

This course provided an introduction to the kinematics of robot arms. Key topics were rigid-body motion, forward kinematics, inverse kinematics, and velocity kinematics. We also covered a small amount of basic computer vision, principally image geometry. We did not have sufficient time to cover path planning, which has often—but not always—been part of the course on campus. I also chose not to cover two more aspects of computer vision, image processing (i.e., blob detection) and camera calibration. These topics were not—in my view—a core part of the intellectual content, were rarely covered in any depth, and were included in the course for the purpose of enabling students to work with real robots in the laboratory. We had to find an alternative way of doing lab work, as I will discuss below. *Robot Modeling and Control* [6] was used as the textbook, just as it had been on campus.

Assessment was based on exams, on homework assignments, and on laboratory assignments. The exams were identical in structure and content to what had been used on campus. The homework assignments, as well, were largely the same. All of these homework assignments, both on campus and at DCC, were designed to be done with pencil, paper, and a calculator. Although students on campus were encouraged to use software tools like MATLAB or Mathematica, students at DCC could rely only on the graphing calculators to which they had been granted access. The laboratory assignments, by necessity, were quite a bit different. On campus, students had been asked to work with a five-joint robot arm in the laboratory, implementing what was being discussed in lecture by doing a small amount of C programming. It was forbidden, as described above, to bring a robot into the prison. As an alternative, I changed the focus to analysis of data that had been collected in the laboratory on campus and brought to students in the prison. Students at DCC were asked to do all of the same types of analysis that they would have done in the laboratory: derive the forward kinematics of the laboratory robot and analyze the error between predicted and actual positions, derive the pose of an object from its location in an image, and so forth. These changes to the laboratory assignments do not, in my view, diminish the intellectual content of the course. Nonetheless, the lack of opportunity for students at DCC to work with a real robot is a clear weakness of the course as it was offered there.

I took the same pedagogical approach in the prison that I had done on campus, with lectures following the Socratic Method. Students at DCC responded equally well to this approach as did students on campus.

One key challenge I faced at DCC that I had not faced on campus was dealing with significant diversity in preparation. All students on campus would have taken calculus and linear algebra, for example, while few students in prison would have taken these courses. I should have, but did not, expect this challenge, and tried to address it in three ways: I took the time in class to review background material, I distributed copies of reference texts on this material, and I provided worksheets that allowed students to practice certain operations—the application of the right-hand rule, the taking of "sine" and "cosine," the multiplication of matrices—using notation consistent with the rest of the course.

ABOUT THE AUTHOR

Timothy Bretl comes from the University of Illinois at Urbana-Champaign, where he is both an Associate Professor and the Associate Head for Undergraduate Programs in the Department of Aerospace Engineering. He holds an affiliate appointment in the Coordinated Science Laboratory, where he leads a research group that works on a diverse set of projects in robotics and neuroscience. He has also received every award for undergraduate teaching that is granted by his department, college, and campus.

TEACHING A UNIVERSITY COURSE ON CONTROL IN PRISON

I taught "AE353: Aerospace Control Systems" in Spring 2016 to six students enrolled at DCC. Four of these students completed the course with a passing grade and received university credit. Two students dropped the course. The grade distribution was the same as would typically be seen on campus. I had taught this course twice before on campus to enrollments of primarily third-year undergraduate students in Aerospace Engineering.

This course provided an introduction to modeling, analysis, and design of linear feedback control systems. I chose to emphasize state-space methods and covered the same topics that I had done on campus: formulation of state-space systems, solution of these systems using the matrix exponential, stability analysis, characteristics of the step response, controllability and state feedback, observability and output feedback, optimal controller and observer design, and the use of Bode plots to characterize frequency response. *Feedback Systems: An Introduction for Scientists and Engineers* [7] was used as the textbook. Copies of the first edition were donated by arrangement with the co-authors and the publisher. We were asked by correctional officers to rebind these copies to remove their hardcovers before giving them to students.

Assessment was based on eight homework assignments and on four in-class exams, all of which were identical in structure and content to what had been used on campus. Exams required only analysis and could be done with pencil and paper. Homework assignments additionally required implementation—plotting the time response, doing eigenvalue placement for higher-order systems, and the like—that had to be done with numerical computation. Students at DCC used python, while students on campus would normally have used MATLAB. I observed the same variation in programming skill among the students at DCC as on campus. Also, just as students do on campus, stronger programmers at DCC shared code to help others make progress.

Just as for the course on robotics, I took a Socratic approach to lecture and addressed diversity in preparation by taking time in class for review and by providing both supplementary material and worksheets for reference. Both time derivatives and differential equations were an area of particular concern for the students. We spent one class session rediscovering the definition of a time derivative as a limit: associating "derivative" first with "rate of change," then with "slope," then with "rise over run," and noticing what happens when the "run" gets close to zero. These connections were in the students' heads but took time to draw out. It was apparent early in the semester that we would have trouble staying on schedule. To address this problem, we chose to keep meeting for two extra months, ending on July 15 instead of May 15.

WHAT I VALUE ABOUT TEACHING IN A PRISON

The prison environment, by design, is one of isolation and oppression [8]. The courses I taught at Danville Correctional Center were imperfect and compromised. I was uncomfortable. Most colleagues did not know what I was doing and could not share my experience.

Why do it?

Teaching in prison has put me in touch with a group of students who share a deep commitment to becoming educated men. It has forced me to work hard on my own teaching practice. It has, through the Education Justice Project, connected me with colleagues who renewed my sense of hope about the possibility of societal change. Put simply, it has contributed to my own flourishing. What better reason is there to put teaching at the center of one's life? [9] ■

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9 This form of the question "Why teach?" comes from C. Higgins, *The Good Life Of Teaching: An Ethics of Professional Practice*, Wiley-Blackwell, 2011 (p. 9), which defends the educational importance of the self-cultivation of the teacher.

ACKNOWLEDGEMENTS

Countless other EJP members make the program what it is. I would like to thank several in particular: Rebecca Ginsburg, EJP Director; Maggie Shelledy and Stephanie Saclarides, Course Coordinators; Peter Campbell, Estibalitz Ezkerra, Millie Wright, and Kate McQueen, fellow instructors and carpoolers; and Andy Borum, coordinator of the EJP computer lab. I would also like to thank the students at DCC, who have helped shape my view of what education can be.