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**SUSTAINABLE REFORM OF AN INTRODUCTORY MECHANICS COURSE
SEQUENCE DRIVEN BY A COMMUNITY OF PRACTICE**

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ABSTRACT

As part of a broader effort to promote the sustainable adoption of evidence-based pedagogies at our institution, the three-course sequence consisting of Introductory Statics, Introductory Dynamics, and Introductory Solid Mechanics has been redesigned to (1) improve students' low engagement and enthusiasm, (2) improve instructors' experience and reduce their high workload, and (3) maintain and elevate the current standards for content. These three courses are the core second-year mechanics classes in our engineering curriculum, serving approximately 2500 students per year from seven engineering departments. To promote sustainability of the reforms, the courses were redesigned through a Community of Practice (CoP), consisting of faculty who collaborated closely to design and implement changes and who developed communal knowledge of the reforms. Evaluation of reforms focused on student satisfaction as expressed through surveys and focus groups.

1 Introduction

The Strategic Instructional Initiatives Program (SIIP) [1, 2] and NSF WIDER@Illinois (Widening Implementation &

Demonstration of Evidence-Based Reforms) project [3] are college-wide efforts to promote the sustainable adoption of evidence-based pedagogies in the College of Engineering at the University of Illinois at Urbana-Champaign. Rather than rely on solitary faculty champions to initiate reforms, SIIP and WIDER@Illinois aim to improve the sustainability of reforms by forming Communities of Practice (CoPs) consisting of instructors who are committed to the reform effort. While these CoPs can be comprised of any number of enthusiastic lecturers and junior faculty, these CoPs are required to also include senior faculty who can broker the departmental buy-in to sustain innovations and reforms. Further, these CoPs are encouraged to meet weekly. During these weekly meetings, representatives from the SIIP or WIDER@Illinois executive teams, comprised of faculty and staff experienced in evidence-based educational methods, facilitate the development and delivery of reforms. This model of collaborative development provides avenues to secure faculty buy-in, organically spread effective practices, facilitate evaluation, and provide just-in-time training for faculty.

As part of the SIIP and WIDER@Illinois project, one CoP has redesigned the introductory mechanics course sequence *Introductory Statics, Introductory Dynamics, and Introductory*

Solid Mechanics. This course sequence is a core component in the second year of our engineering curriculum, serving approximately 2500 students per year. The primary objectives of these course reforms were to: (1) improve students' low engagement and enthusiasm, (2) improve instructors' experience and reduce their high workload, and (3) maintain and elevate the current standards for content. Unlike some reform efforts, the primary goal was not short-term improvements in student grades or other learning-outcome measures, but rather to establish a sustainable environment for innovation and improvement over the longer term.

Prior to reform, the teaching format for the three introductory mechanics courses involved 3 hours per week of lecture, with one instructor and about 250 students, 1 hour per week of a discussion section, with 1 teaching assistant and about 30 students, and an expected 4 to 6 hours of additional work by students. Both lecture and discussion sections were typically taught in a "lecture" style, with the students primarily watching the instructor and taking notes. The content included standard vector mechanics material and focused on derivations and worked problems, with limited applied examples. The courses suffered from low engagement and enthusiasm on the part of both students and instructors. Students routinely reported that these courses were their least-favorite courses in the curriculum, and the department faced a constant struggle to persuade faculty to teach the courses. Instructors reported that the courses had a higher-than-normal teaching workload.

The pedagogical reforms undertaken in the introductory mechanics courses involved the following key changes: (1) an active learning discussion section format with a focus on "real-world" applications of the course material; (2) a collaborative learning format in discussion sections based on group work; (3) active learning in lectures using classroom response systems (using the *i>clicker* system); (4) online interactive homeworks with immediate feedback; and (5) online help forums to largely substitute for in-person office hours (using the *Piazza* website). These changes retained the weekly course format and expected time commitment for students. The use of technology-intensive instructional strategies has moved these courses to a blended model, which combines aspects of online delivery with in-person interactions.

These evidence-based reforms were supported by a collaborative instructional team and implemented using an innovate-evaluate feedback cycle (see Figure 1). The collaborative instructional team consisted of faculty and lecturers as well as the teaching assistants for the courses, and also included faculty who were not teaching the courses in the current semester but who were part of the CoP for the courses. The teaching assistants received training in group-work facilitation and online student interaction, and collaborated with each other and with instructors in the implementation of reforms.

2 Communities of Practice for Reform

The past 15 years have created a surge in research documenting how instructors' implicit epistemologies, beliefs, and commitments drive decision making during instruction and resist productive changes toward evidence-based pedagogies [4–12]. Unfortunately, the standard methods of dissemination in academia (e.g., articles, workshops, seminars, etc.) are ineffective at changing these belief systems, because these methods are appropriate for *technical change* efforts rather than *adaptive change* efforts [13–15]. Transformational Learning Theory tells us that technical changes simply require the acquisition of new skills or knowledge to effect change, while adaptive changes inherently challenge core beliefs or epistemologies of the individuals or institutions who are adopting the change [13]. Adaptive changes may be technically simple (e.g., asking more questions in class), but they are difficult to achieve because challenging core beliefs activates a psychological "immune system" that resists change (e.g., asking more questions challenges a primary identity of "instructor as knowledge disseminator") [13, 16]. Consequently, while "top-down" mandates or isolated development of "best practices" followed by dissemination have proven ineffective in promoting the adoption of evidence-based practices [14, 17], long-term strategies that focus on changing faculty beliefs, motivation, and institutional culture have proven effective [14, 17].

Consequently, both the SIIP and WIDER@Illinois project have adopted a long-term strategy focused on creating cultural change. In contrast to large-scale reform efforts that focus on promoting the adoption of specific pedagogies, our model of reform focuses on creating instructional cultures within departments that will foster environments from which adoption of evidence-based pedagogies will emerge. This "culture reform" model relies on a series of three transformations to achieve improvements in instruction. The first transformations support the later transformations (see Figure 1). These transformations are supported by embedding faculty within, or creating new, CoPs focused on creating ongoing, iterative improvements.

Transformation 1: Connecting faculty in Communities of Practice. Teaching traditionally occurs in isolation. Choices of pedagogies and content within a course change as often as the instructors do. This isolationist culture limits the spread of pedagogical advances among faculty and across campus as dissemination relies on secondary efforts divorced from the delivery of the course. In contrast, the goal of SIIP is to create a collaborative teaching culture that will create departmentally or communally owned courses. This collaborative joint ownership of courses provides the cultural basis for creating ongoing, scholarly reform.

Transformation 2: Continual improvement via feedback and evaluation. The isolationist culture also inhibits the ability of faculty to compare and evaluate the advantages of different ped-

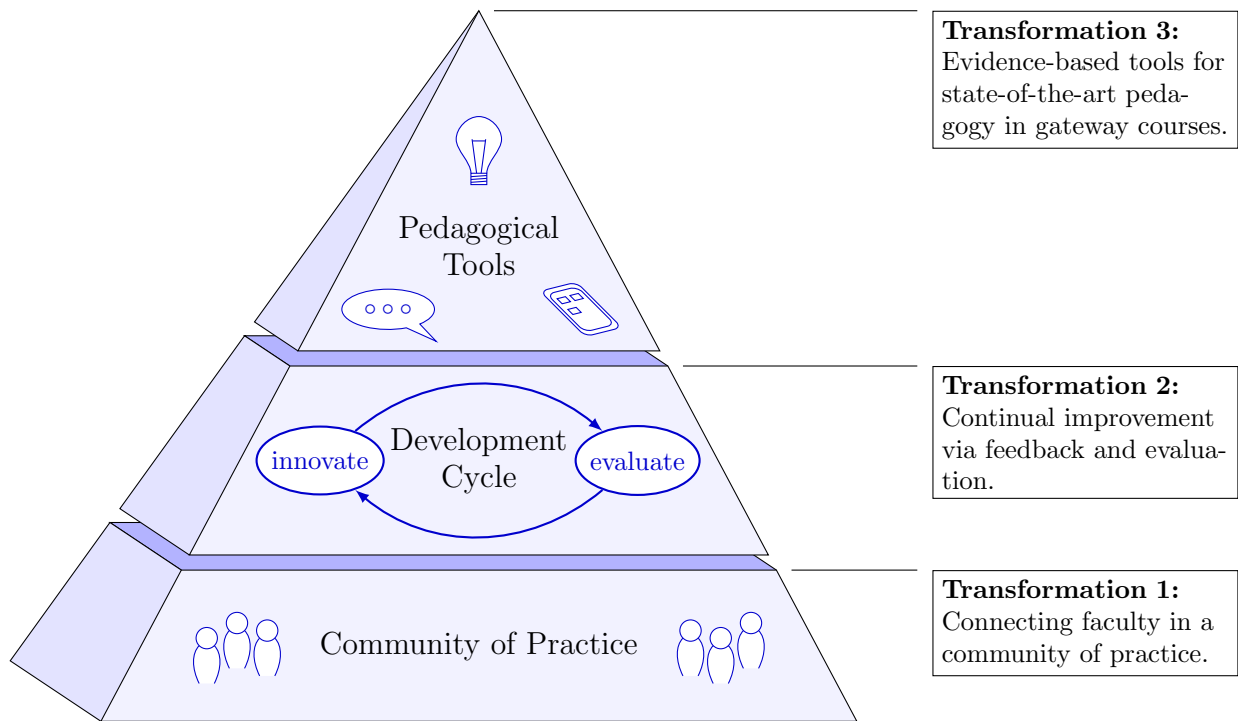


FIGURE 1. THE “PYRAMID OF CHANGE”, SHOWING THE THREE LEVELS OF TRANSFORMATION THAT ENABLE THE OBJECTIVES OF THIS PROJECT; EACH LAYER SUPPORTS THE TRANSFORMATIONS ABOVE.

agogy as faculty teach different content, do not collect data, or resist the implications of data that they did not collect. By creating joint course ownership, faculty are able to participate in an implement-evaluate development cycle. This cycle begins by identifying areas for improvement. Then faculty implement targeted reforms and evaluate whether these reforms produce the desired improvements, and then repeatedly iterate the process.

Transformation 3: Organic adoption of evidence-based pedagogies. The collaborative culture and the scholarly implement-evaluate cycle require faculty to engage in ongoing dialogue about how to improve students’ learning and experiences. These dialogues allow the CoP to identify areas for improvement and evidence that community members agree are trustworthy, and they allow expertise and beliefs within the group to spread. As faculty agree on areas for improvement and evidence, they can develop consensus on which evidence-based pedagogies to adopt. Further, by creating a CoP of committed faculty, the choice of evidence-based pedagogies will better match the existing departmental culture, promoting acceptance. The CoP rather than an individual then sustains the innovation, distributing the workload and providing mutual support.

3 A Case Study in Creating Sustainable Reform

The basis for reform efforts in the three introductory mechanics courses is a close-knit group of faculty collaborating in a CoP. This group meets weekly both in and out of semester, with meetings being used for reform planning, implementation logistics, evaluation analysis, and general discussions relating to pedagogy and teaching organization. Within the CoP structure, one or two faculty typically take the lead on developing and implementing particular innovations, with the other faculty supporting the effort, providing feedback, and assisting with evaluation. Successful reforms are iterated upon by several faculty, and are codified in written form for the use of new community members, teaching assistants, and faculty in other departments or universities. A summary of the reforms implemented is shown in Table 1.

A fundamental tenet for the CoP is that the course is “owned” by the team, rather than by whichever faculty happen to be teaching it in a given semester (see Table 2). This represents a dramatic shift from established departmental practice, but is crucial for enabling complex reforms that require multiple semesters to develop, implement, and iterate. Shifting to a team-ownership model required a complex and on-going negotiation between faculty, many of whom have strong opinions on content and pedagogy. The CoP has adopted a flexible model where faculty voluntarily maintain and extend existing course structures, but in which individual faculty still retain freedom

Reform type	List of reforms
Online technology	Online homework systems (<i>Mastering Engineering</i> and <i>PrairieLearn</i> [18]), online help/discussion forum (<i>Piazza</i>), multimedia online notes, integrated online gradebooks, online presentation of honors projects.
In-class technology	Classroom response system (<i>i>clicker</i>), lectures delivered on tablet computers, lectures recorded for later online viewing (<i>Echo360</i>), computerized testing facility for exams [19].
Organization	Team ownership of courses, TA training and mentoring, per-course TA weekly meeting, weekly CoP faculty meeting, standardized office hours location and scheduling, written documentation of processes and policies, randomized per-student multiple-choice exams (<i>randexam</i> [20]).
Evaluation	Standardized mid-semester course surveys, focus group student feedback, pre- and post-semester concept inventories.
Other pedagogy	Active learning in lectures, collaborative learning via group work in discussion sections [21], active learning in discussions sections, “real-world” applications for long-form assignments.

TABLE 1. SUMMARY OF REFORMS IMPLEMENTED IN *INTRODUCTORY DYNAMICS* AND SUBSEQUENTLY EXTENDED TO OTHER SOPHOMORE DYNAMICS COURSES, FOLLOWING THE TIMETABLE SHOWN IN FIGURE 2. SEE SECTIONS 3 AND 4 FOR DISCUSSION.

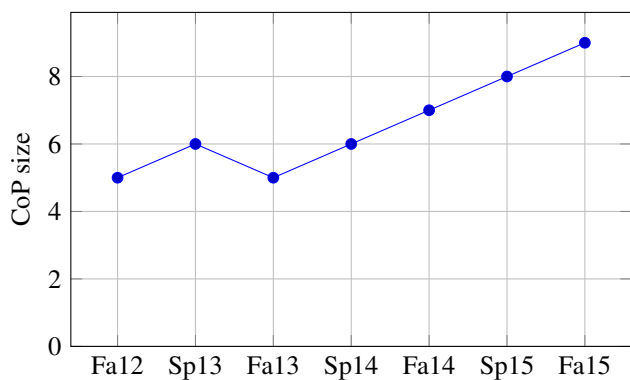


FIGURE 2. NUMBER OF FACULTY MEMBERS IN THE COMMUNITY OF PRACTICE (COP) FROM ITS INCEPTION IN THE FALL 2012 SEMESTER TO FALL 2015. SEE FIGURE 3 FOR A DETAILED BREAKDOWN OF COP MEMBER ROLES, AND REFER TO SECTION 3 FOR DISCUSSION.

regarding implementation in their classes each semester. This “voluntary collaboration” model has proved very successful in maintaining both tight integration between faculty and autonomy of each faculty member.

As shown in Table 2, the CoP initially started with five members, but one withdrew early due to incompatibility in the vision for an integrated teaching team for this set of courses. This withdrawal was in fact crucial to the productive functioning of the CoP, as integrated team functioning can be easily undermined if even one team member does not share the overall goal, and meant that reforms were only introduced to *Introductory Statics*

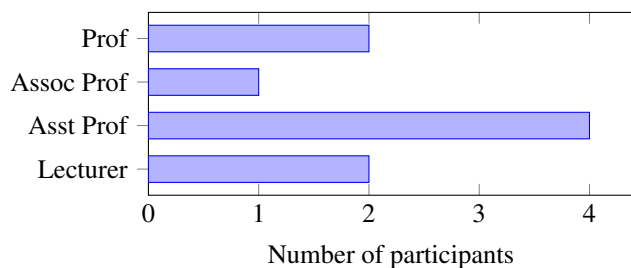


FIGURE 3. ACADEMIC RANK COMPOSITION OF THE COMMUNITY OF PRACTICE (COP) AS OF 2015. THIS COP HAS A MIXTURE OF TENURE-TRACK (ASSISTANT, ASSOCIATE, AND FULL PROFESSOR) MEMBERS AS WELL AS NON-TENURE-TRACK (LECTURER) MEMBERS, AND A SPREAD OF MEMBER RANK AND EXPERIENCE. SEE TABLE 2 FOR THE TIMETABLE OF WHEN MEMBERS JOINED THE COP AND SECTION 3 FOR DETAILED DISCUSSION.

in Fall 2014. Over the seven semesters of its existence to date, the CoP has grown by adding new members to its current size of nine. The distribution of faculty ranks within the team is shown in Figure 3, from which it is apparent that the team is highly diverse in terms of background and experience level. The CoP is also diverse in gender, with 33% women members, which is significantly higher than the departmental average.

Communication within the CoP occurs over a variety of channels, as shown in Figure 4. There are weekly meetings of the CoP which directly connect members in both long-range and short-range planning, and deeper one-on-one connections are also built by co-teaching arrangements and teaching-support ar-

Instructor	Fall 2012	Spring 2013	Fall 2013	Spring 2014	Fall 2014	Spring 2015	Fall 2015
A. Lecturer	Statics	Statics					
B. Prof	CoP	CoP	Dynamics	CoP	Dynamics	CoP	CoP
C. Prof	Dynamics	CoP	CoP	CoP	Statics	CoP	Statics
D. Assoc Prof	CoP	Dynamics	CoP	CoP	CoP	Dynamics	Dynamics
E. Lecturer	Solids	Solids	Solids	Solids	Statics	Statics	Solids
F. Asst Prof		Dynamics	CoP	Dynamics	CoP	Dynamics	CoP
G. Lecturer				Dynamics	CoP	Solids	CoP
H. Asst Prof					Solids	CoP	CoP
I. Asst Prof						Solids	CoP
J. Asst Prof							Statics

TABLE 2. TIMETABLE OF THE GROWTH OF THE COMMUNITY OF PRACTICE OVER SEVEN SEMESTERS FROM FALL 2012 TO FALL 2015. THE ORIGINAL TEAM CONSISTED OF FIVE PEOPLE, ONE OF WHOM LATER LEFT THE TEAM. A “STEADY GROWTH” MODEL WAS USED TO GROW THE TEAM FROM THE FOUR ORIGINAL CORE MEMBERS TO A CURRENT SIZE OF NINE. AS OF 2015, ANY GIVEN SEMESTER HAS FOUR OR FIVE TEAM MEMBERS ACTIVELY TEACHING ONE OF THE MECHANICS COURSES (SHOWN IN BOLD TEXT), DUE TO DIFFERING NUMBERS OF COURSE SECTIONS IN SPRING AND FALL, WITH THE REMAINING TEAM MEMBERS MAINTAINING INVOLVEMENT IN THE COMMUNITY OF PRACTICE VIA REGULAR TEAM MEETINGS (DENOTED “COP” IN THE TABLE). WORK IN FALL 2015 IS PLANNED, WHILE WORK PRIOR TO THIS IS COMPLETED AT THE TIME OF WRITING. SEE SECTION 3 FOR DISCUSSION.

rangements (for instructors teaching a course for the first time). These involve meetings multiple times per week on the details of course content, and enable CoP members to work together in a deep way. Over time, every CoP member has had such a deep connection for at least one semester with at least one other CoP member, in addition to the weekly whole-CoP meetings.

Due to the close connections and shared vision, the CoP has established a high level of trust between faculty over time, which is key to undertaking risky innovations. This CoP has adopted a highly entrepreneurial methodology, with a preference for fast iteration on new pedagogical styles. For example, the group-work discussion section format was implemented in Spring 2013 with previously-untested worksheets. Initial feedback from students and teaching assistants in the first week indicated that different groups worked at very different speeds, so a system of “optional” questions was implemented for Week 2 that enabled all groups to work for the entire discussion section. Similar iteration on the format details occurred for several weeks until a well-functioning system was established. The CoP was highly supportive during the initial development phase, with all members eager to continue innovation until a good outcome was achieved.

As well as a general agreement on innovation style, the CoP also reached early and sustained agreement on several broad themes. Perhaps most important among these was the role of technology, with all CoP members enthusiastically embracing

the use of digital technologies both inside and outside the classroom wherever their use facilitated student learning or improved course functioning. Collaboration proved essential in adopting new technology, as there was often a steep initial learning curve and significant iteration required for effective use. For example, the online discussion forum was first piloted using a “best-effort” system for monitoring by teaching assistants. This resulted in irregular monitoring, and students quickly learned that they could not rely on a prompt response, leading to poor overall usage of the forum. The following semester a much more rigorous timetable was enforced for teaching-assistant engagement online, leading to a very positive feedback with student use and resulting in very high usage levels and student satisfaction with the tool. This successful combination of a technology (the online forum) and organization system (teaching-assistant scheduling and training) was then codified in written form and has been successfully implemented in subsequent semesters. The extensive use of online technology, resulting in a blended learning environment [22], has both directly facilitated student learning as well as reducing instructor workload on menial tasks, allowing for greater emphasis on student-instructor interactions.

An important element for the development of the CoP was support from administration in the college and department at the University of Illinois at Urbana-Champaign. SIIP was instrumental in initiating the reform effort and lead directly to the for-

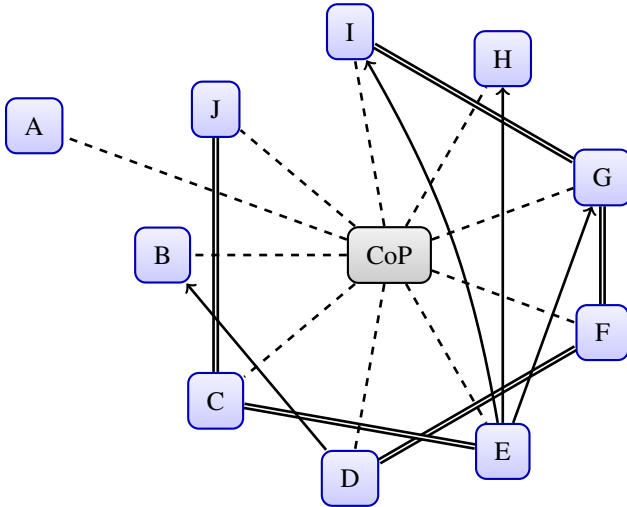


FIGURE 4. CONNECTIVITY DIAGRAM OF INSTRUCTORS. ALL INSTRUCTORS WERE CONNECTED VIA THE COMMUNITY OF PRACTICE (CoP), INDICATED BY DASHED LINES. IN ADDITION, SOME INSTRUCTORS CO-TOUGHT TOGETHER (DOUBLE LINES) OR ACTED AS SUPPORT DURING A FIRST SEMESTER OF TEACHING (SOLID SINGLE LINES WITH ARROWS INDICATING DIRECTION OF SUPPORT). WITH THE EXCEPTION OF INSTRUCTOR A, ALL CoP MEMBERS CO-TOUGHT OR WORKED IN A SUPPORT RELATIONSHIP WITH AT LEAST ONE OTHER CoP MEMBER. CO-TEACHING RELATIONSHIPS CAN ALSO BE SEEN IN TABLE 2, AND THE IMPLICATIONS OF THIS CLOSE CONNECTIVITY IS DISCUSSED IN SECTION 3.

mation of the CoP, and the formal SIIP process (funding, education, review, etc.) has been extremely helpful in formalizing and rewarding the CoP. The departmental administration has also been highly supportive of the reform efforts, which has been essential for success of the endeavor. For example, the department has ensured that teaching appointments are made consistent with the CoP’s plans for course reform, and provided a 50% increase in the number of teaching assistants to enable the reduction of discussion section sizes from 30 to 20 students as part of the group-work and active-learning discussion format. The support of the departmental and college administrations has required substantial financial investment as well as administrative good-will, but it is hard to imagine how the reform efforts could have succeeded without this support.

4 Evaluation and Outcomes

The various reforms were progressively developed and evaluated, with full implementation for *Introductory Dynamics* and *Introductory Solid Mechanics* in the Spring 2013 semester, and implementation for *Introductory Statics* in Fall 2014. Usage and engagement metrics were measured both online and offline, and

student opinions and beliefs were measured by paper surveys and in-person focus groups conducted by an external evaluator. As described in Section 1, the three primary objectives of the reform effort were:

- Objective 1:** Improve students’ low engagement and enthusiasm while taking the courses.
- Objective 2:** Improve instructors’ experience and reduce their high workload while teaching the courses.
- Objective 3:** Maintain and elevate the current standards for content within the courses.

Although a very large number of individual reforms were made to the courses (see Table 1), the five key reforms listed in Section 1 are especially important from an evaluation standpoint. They are:

- Reform 1:** Active learning discussion section format with a focus on “real-world” applications of the course material.
- Reform 2:** Collaborative learning format in discussion sections based on group work.
- Reform 3:** Active learning in lectures using classroom response systems (using the *i>clicker* system).
- Reform 4:** Online interactive homeworks with immediate feedback (using *Mastering Engineering* and *PrairieLearn* [18]).
- Reform 5:** Online help forums to largely substitute for in-person office hours (using the *Piazza* website).

Objective 1 was evaluated by measuring student attendance rates and student opinions on the courses. Figure 5 shows attendance rates in a representative semester and course (Spring 2013, *Introductory Dynamics*). The use of active learning in both lectures and discussion sections resulted in high attendance rates, with average attendance rates of 82.0% in lectures and 88.3% in discussion sections. This compares with attendance rates below 50% in comparable courses pre-reform, and thus represents a large increase in attendance. The slight decline in Figure 5 is most likely attributable to two factors: (1) students were permitted to drop the lowest two discussion-section scores in the semester, so many chose to not attend one or two classes towards the end; and (2) the pressure of exam study and final projects and papers in other courses typically leads to somewhat lower attendance near the end of semester.

Student opinions on Reforms 1–5 were evaluated by paper-based surveys each semester. Representative results (all three courses in Spring 2015) are shown in Table 3. From this we see that, not only were attendance rates high, but students also found both lectures and discussions to be valuable, with satisfaction ratings of 88% for discussion sections and 87% for lectures (average rating or higher on questions 1 and 3 in Table 3). This suggests that Reforms 1 and 3 (active learning in lectures and discussions) were well-received by students.

Reform 2 (collaborative learning) was evaluated by question 2 in Table 3, and shows that 90% of students preferred to work in

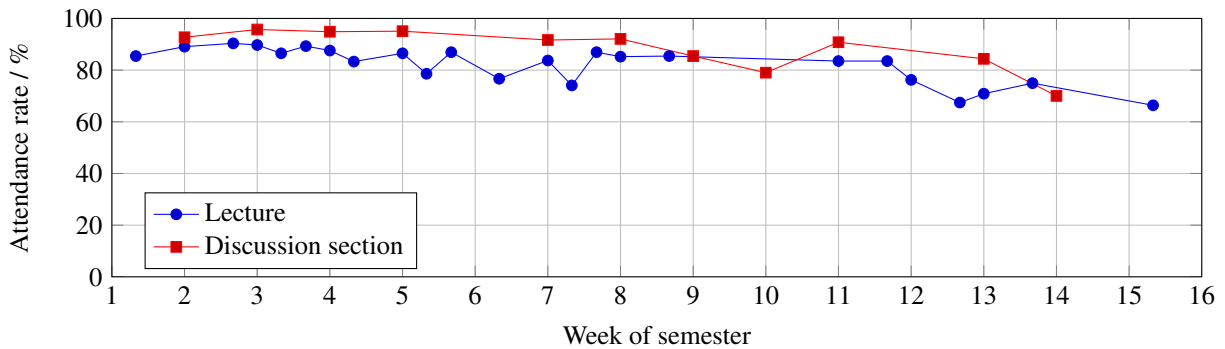


FIGURE 5. ATTENDANCE RATES IN LECTURES AND DISCUSSION SECTIONS FOR *INTRODUCTORY DYNAMICS* IN THE SPRING 2013 SEMESTER. THE AVERAGE ATTENDANCE RATE WERE 82.0% FOR LECTURES AND 88.3% FOR DISCUSSION SECTIONS. SEE SECTION 4 FOR DISCUSSION.

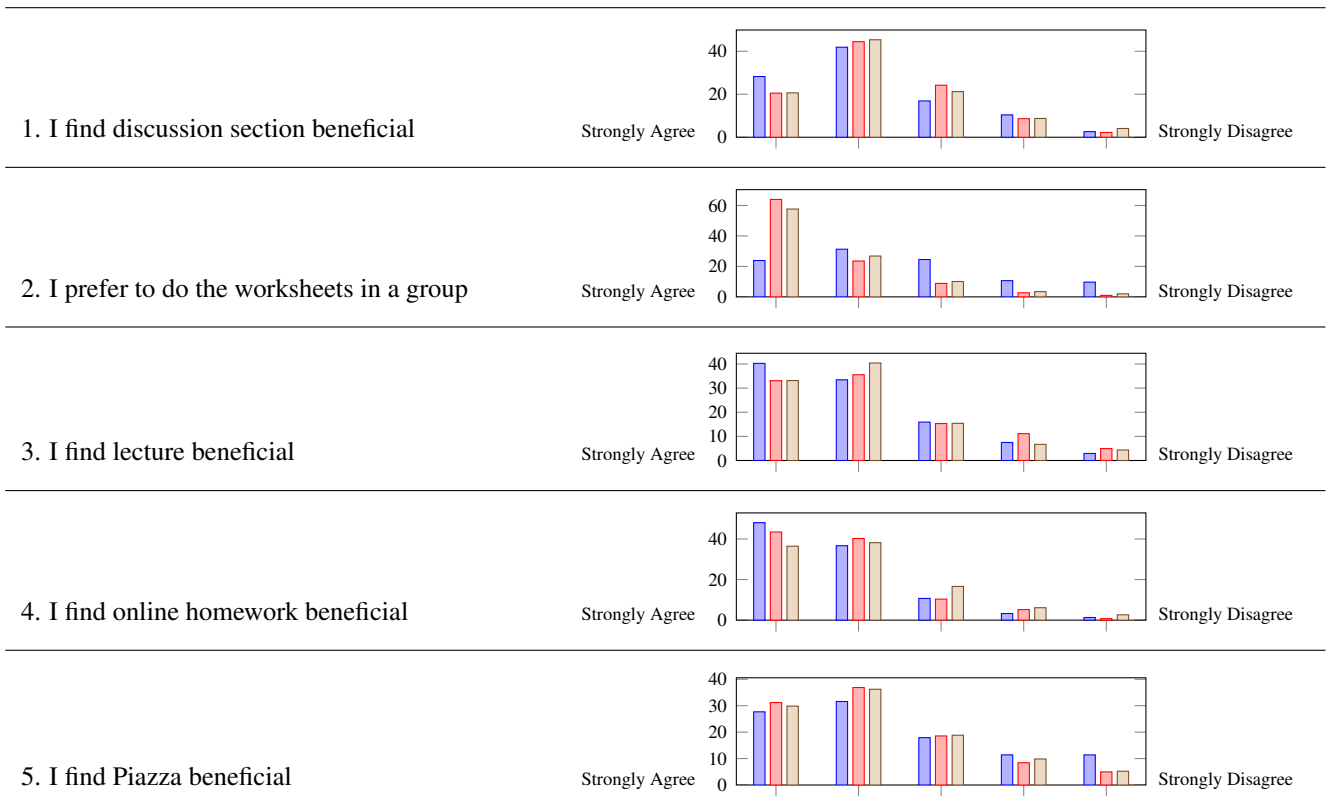


TABLE 3. STUDENT SATISFACTION WITH THE FIVE KEY PEDAGOGICAL REFORMS LISTED IN SECTION 4, SHOWING GENERALLY VERY HIGH STUDENT SATISFACTION IN ALL THREE INTRODUCTORY MECHANICS COURSES (BLUE: STATICS, RED: DYNAMICS, YELLOW: SOLIDS). SURVEY RESULTS ARE FROM SPRING 2015. *INTRODUCTORY STATICS* (BLUE) HAD $N = 317$ STUDENTS RESPONSES (91% RESPONSE RATE), *INTRODUCTORY DYNAMICS* (RED) HAD $N = 411$ STUDENT RESPONSES (86% RESPONSE RATE), AND *INTRODUCTORY SOLID MECHANICS* (YELLOW) HAD $N = 351$ STUDENT RESPONSES (90% RESPONSE RATE). ALL QUESTIONS USED 5-LEVEL LIKERT-TYPE SCALES, AND THE VERTICAL AXES SHOW THE PERCENTAGE OF STUDENTS GIVING EACH RESPONSE IN EACH COURSE.

groups (average rating or higher) across all three courses. When broken down by course, the two courses with the longest experience in group work (*Dynamics* and *Solids*) had student approval ratings of 96% and 95% respectively for group work, while the newest course to introduce this change (*Statics*) had an approval rating of 80%, suggesting that some improvements can still be made to the collaborative learning discussions in *Statics*.

This initial student resistance to collaborative learning (group work) in discussion sections also manifested itself in the first use of this pedagogical technique in *Introductory Dynamics* during Spring 2013. Although the discussion sections were eventually very popular with students, the use of group work in discussions was initially a highly contentious idea, with students organizing complaints and lobbying online and in-person to change back to individual work. By mid-semester, however, student opinion had dramatically shifted, with just 11% of students expressing a desire to work in an individual setting and an overall 90% satisfaction rating with discussion sections. By Spring 2015, only 4% of students desired to work individually, indicating that this reform was well-established in this course.

Reforms 4 and 5 involved the use of online technologies, specifically online homeworks and online help forums (Piazza), respectively. As shown in Table 3 questions 4 and 5, both components were popular with students, with approval ratings of 94% for online homeworks and 83% for the Piazza online help forum (average rating or higher).

The online components of the course also had very high usage rates, with all students using the online homework system and the other web components having usage rates as shown in Figure 6. The online-help-forum usage rates varied by student, as shown in Figure 7. While most students used the forum at least once per week on average, a small fraction of students were responsible for most of the posts, as is common for many online content-creation activities [23, 24] (sometimes known as the “1% rule” or “90-10-1” principle). This is captured in Figure 8, which shows the fraction of students responsible for the corresponding fraction of contributions online. Despite the fact that 46% of students never posted to the forum, only 13% of students were dissatisfied with the forum as a means of interaction and obtaining help, indicating that for a sizable group of students it was sufficient to simply read posting by other students and course instructors.

Objective 2 (improving instructors’ experience) is difficult to measure objectively. One clear indication of improvement in this regard is the significant and steady growth in the CoP, as shown in Table 2. These courses have historically had great difficulty in attracting instructors at all, with many faculty teaching them once and then not wanting to do so again. Not only has the CoP grown significantly, but CoP members are choosing to repeatedly teach the introductory mechanics courses and to continue to improve them. Anecdotal evidence also suggests that the instructor workload has been reduced for these courses, but

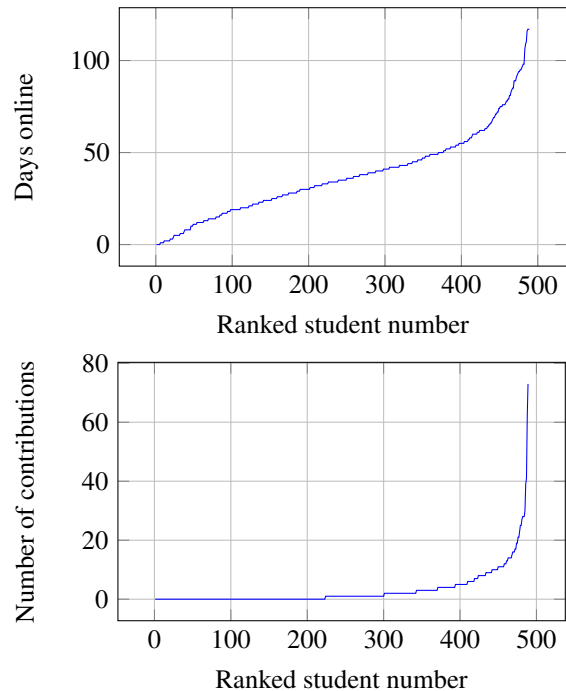


FIGURE 7. ONLINE-HELP-FORUM USAGE DATA FOR *INTRODUCTORY DYNAMICS* IN THE SPRING 2013 SEMESTER, SHOWING THE NUMBER OF DAYS ONLINE (LEFT) AND NUMBER OF CONTRIBUTIONS (RIGHT) BY STUDENT NUMBER. CONTRIBUTIONS INCLUDE QUESTIONS, ANSWERS, AND NOTES. OBSERVE THAT 46% OF THE STUDENTS NEVER POSTED DURING THE SEMESTER, BUT NEARLY ALL STUDENTS LOGGED ON REPEATEDLY, WITH MOST STUDENTS LOGGING ONTO THE FORUM SEVERAL TIMES PER WEEK ON AVERAGE. SEE SECTION 4 FOR DISCUSSION.

it still remains high.

Precise evaluation of Objective 3 (maintain content standards) is also challenging to measure, due to changes in exam format (long answer to multiple choice) and an increased emphasis on conceptual problems on exams, which makes direct comparison of grades challenging. Nonetheless, Figure 9 shows the GPA (Grade Point Average) for all three mechanics courses averaged before and after the reforms were introduced, for which there was a consistent increase of almost half a grade across the three courses (average increase of 0.39 on a 4.0 scale). Anecdotal evidence also suggests that student learning objectives continue to be met in all three courses, and further improvement in this area is a future goal of the project.

5 Future Work

At this point, the efforts of the CoP have made significant strides in attaining the first two goals of the reform effort: (1)

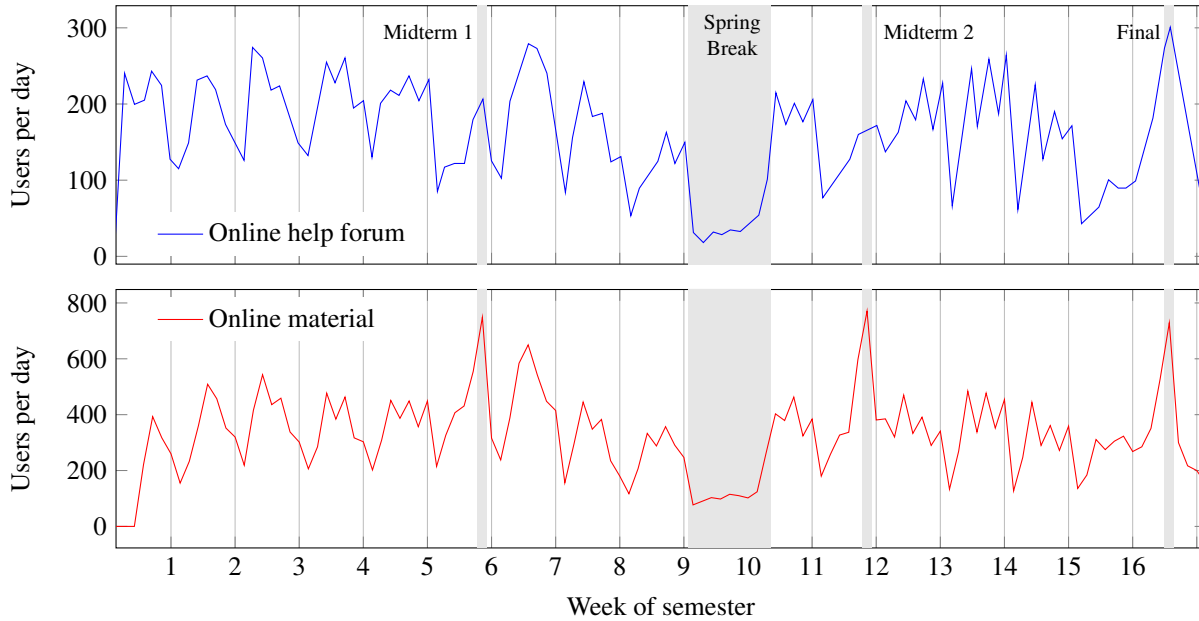


FIGURE 6. WEB SITE TRAFFIC FOR THE ONLINE FORUM (TOP) AND THE ONLINE COURSE MATERIAL (BOTTOM) FOR *INTRODUCTORY DYNAMICS* IN THE SPRING 2013 SEMESTER. THE VERTICAL GRID LINES ARE MARKED ON FRIDAYS, WHICH IS WHEN THE HOMEWORK WAS DUE EACH WEEK. OBSERVE THAT THERE IS NOT A SPIKE IN USAGE JUST BEFORE HOMEWORKS ARE DUE. INSTEAD, TRAFFIC AND ACTIVITY IS EVENLY SPREAD THROUGHOUT THE WEEK. SEE SECTION 4 FOR DISCUSSION.

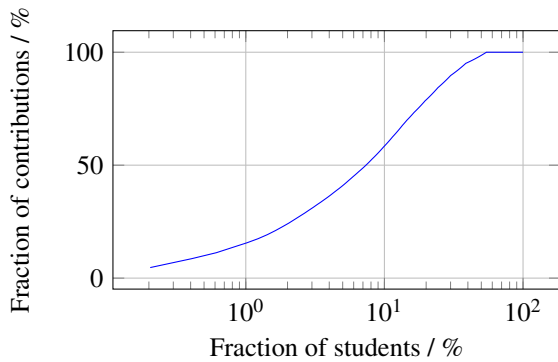


FIGURE 8. ONLINE-HELP-FORUM USAGE DATA FOR *INTRODUCTORY DYNAMICS* IN THE SPRING 2013 SEMESTER, SHOWING THE FRACTION OF STUDENTS RESPONSIBLE FOR EACH FRACTION OF CONTRIBUTIONS. NOTE THAT THE HORIZONTAL SCALE IS LOGARITHMIC. THE INDIVIDUAL MOST-ACTIVE STUDENT MADE ABOUT 5% OF CONTRIBUTIONS ALONE; THE MOST ACTIVE 1% OF STUDENTS MADE 16% OF CONTRIBUTIONS; AND THE MOST ACTIVE 10% OF STUDENTS MADE 58% OF CONTRIBUTIONS. A TOTAL OF 54% OF STUDENTS MADE SOME CONTRIBUTION DURING THE SEMESTER. SEE SECTION 4 FOR DISCUSSION.

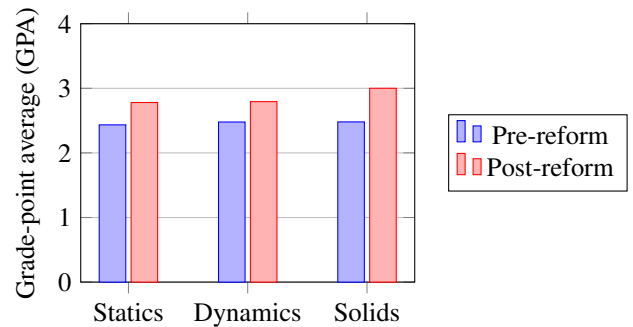


FIGURE 9. GRADE POINT AVERAGE (GPA) IN EACH OF THE THREE MECHANICS COURSES PRE- AND POST-REFORM. GRADES IN *INTRODUCTORY DYNAMICS* AND *INTRODUCTORY SOLID MECHANICS* WERE AVERAGED FROM SPRING 2010 TO SPRING 2012 FOR PRE-REFORM, AND FROM FALL 2012 TO SPRING 2015 FOR POST-REFORM, BASED ON THE INTRODUCTION OF REFORMS IN FALL 2012 (SEE TABLE 2 AND USING THE MAXIMUM EXTENT OF AVAILABLE DATA). GRADES IN *INTRODUCTORY STATICS* WERE AVERAGED FROM SPRING 2010 TO SPRING 2014 FOR PRE-REFORM, AND FROM FALL 2014 TO SPRING 2015 FOR POST-REFORM, AGAIN BASED ON THE REFORM INTRODUCTION DATE OF FALL 2014 AS SHOWN IN TABLE 2. SEE SECTION 4 FOR DISCUSSION.

improve students' low engagement and enthusiasm; and (2) improve instructors' experience and reduce their high workload. The reform efforts in the three-course introductory mechanics sequence will focus on the third objective of maintaining and elevating the current standards for content. Evaluation of the reform will measure and evaluate students' preparation for future coursework and their learning outcomes.

A key challenge for the reform project is the continuation of the CoP. By incorporating all three sophomore mechanics courses into a single CoP, a critical mass of faculty has been established that has sufficient size to be robust against the usual changes in faculty teaching availability. Additionally, the sense of camaraderie engendered by the CoP assists in maintaining engagement. However, it remains to be seen whether recruitment of new faculty into the CoP will continue, and whether the structure is sustainable in the long term.

6 Reflections and Recommendations

The formation of a CoP to reform and improve the introductory mechanics course sequence has provided a proof-of-concept for the effectiveness of the CoP model of education reform. Not only have student and faculty attitudes toward the course improved, but it has also demonstrated encouraging initial growth and sustainability over seven semesters. The reliance on community rather than individuals has sustained the reforms through multiple instructors and multiple semesters.

Although this CoP model has proved effective, it has not necessarily been easy to implement. Of the 17 teams of faculty engaged in SIIP, four have struggled to create anything resembling a CoP [25]. While these faculty clearly desire to improve education, entrenched values of "academic freedom" and an individualistic teaching culture impede creation of the CoPs. Similarly, the language of CoPs (even the phrase "community of practice") have served as a barrier to faculty adoption. Careful messaging and careful identification of teachable faculty has been essential.

Despite these new barriers to change, the CoP model has enabled the SIIP and WIDER@Illinois project to overcome traditional barriers to change. By focusing CoPs around the goal of ongoing improvement of core engineering courses, we were able to engage many faculty who had previously never been involved in faculty development for their teaching. The CoP model provided just-in-time training and apprenticeship for these faculty as they worked alongside more experienced faculty. Similarly, by integrating support personnel within the CoPs, they were able to identify and meet needs as they arose, shortening the feedback cycle and reducing the repetition of mistakes. Similarly, as faculty have engaged in this CoP model, they have become advocates for the model among their peers. This "native" faculty voice, we believe, is ultimately the solution to drawing resistant and hesitant faculty into this new model for education reform.

While garnering this bottom-up support from the faculty CoPs is essential, garnering the top-down support of administration is equally critical. Funding from the Deans has been an essential incentive for inviting faculty into the CoPs and for supplying pedagogical expertise to the CoPs. Departmental administration support through arrangement of teaching schedules, room requests, additional teaching assistant support, and other course logistics is vital to the success of the CoPs. Unless the CoP has input on who will teach a course or where/when the course will be taught, the effectiveness of the CoP can be limited or even negated.

The creation of faculty CoPs offers many avenues for future research on creating sustainable education reform. What are the marks of effective and ineffective faculty CoPs? What type of administrative or cultural support is necessary to create effective CoPs? How do faculty beliefs about teaching and learning change in response to participating in CoPs? Are CoP-driven reforms truly sustainable? How can faculty CoPs be institutionalized to promote their sustainability?

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