RESEARCH-ARTICLE

Faculty Adoption of CS Education Innovations: Exploring Continued Use

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Faculty Adoption of CS Education Innovations: Exploring Continued Use

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ABSTRACT

Studies on faculty adoption typically focus on the awareness and trial stages: how instructors find out about a new teaching practice and why they decide to try it. While this knowledge is important, reform is unlikely to occur if innovations are only used experimentally; we need to understand why faculty sustain their use. To that end, this study draws on data from a two-phase project in the U.S. to examine why computer science (CS) faculty continue or discontinue use of a practice after the initial trial. In the first phase, we interviewed and observed 66 CS faculty from various institutional settings to explore theory-driven themes. From these results, in the second phase, we collected survey data from 821 faculty at 595 institutions. In this paper, we briefly discuss qualitative results, and then use quantitative data to model what impact the following factors have on sustaining use: *achieved benefits for students' performance and their satisfaction in CS, the perception of usefulness to the instructor, student feedback*, and *ease of use*. Results indicate that benefits to students' performance are paramount in predicting continued use. We also explore why faculty abandon a practice, finding that the decision often relates to not achieving desired outcomes and, in some cases, students not making a good faith effort to do their part. We observed that the latter experience can engender negative beliefs about students—that they have, at best, a passive attitude toward their learning. Implications for encouraging sustained usage of innovative teaching techniques are discussed.

KEYWORDS

faculty adoption; sustaining use; innovative teaching practices; student-centered teaching; propagation; diffusion of innovations

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1 INTRODUCTION

In 2017, approximately 20% of bachelor's degrees in computer and information sciences were conferred to women; only 6% were conferred to women of color [26]. Slight increases in participation among women overall in the last decade [4] do not abate the stark disproportion of degree conferrals, nor does it address that participation among women of color in CS has actually decreased over the same timeframe [22]. Many student-centered practices have demonstrated success in bolstering engagement, learning, satisfaction, and persistence [10], and in addressing barriers to attracting and retaining women and people of color in CS [3, 22, 28]. And yet, achieving widespread adoption and sustained use of these practices remains elusive. Research suggests that although most CS faculty experiment with student-centered practices [16] and see themselves as using both instructor- and student-centered practices equally [12, 13], lecturing remains the signature pedagogy of the discipline [16].

To determine why innovative teaching has not diffused more widely, higher education research has typically examined how faculty find out about innovations, and what motivates faculty to try them. A review of this literature in CS and STEM undergraduate settings is available in [24], and [17] reports literature and findings related to awareness and trial stages among CS faculty using the same dataset we use here. However, encouraging more faculty to try innovations is only a start. Faculty need to continue using them in a meaningful and sustained way.

In this paper, we present results from a two-phase project that uses both qualitative (phase 1) and quantitative (phase 2) data on how and why CS faculty in the U.S. find out about, try out, and routinely use new teaching practices. Specifically, here we investigate what motivates CS faculty (professors, instructors, lecturers, etc.) to sustain their use of an innovation after the initial trial. Results addressing other stages of adoption are reported elsewhere in [1, 2, 16, 17].

2 QUALITATIVE METHODS

In phase 1, we conducted semi-structured interviews, focus groups, and classroom observations with 66 introductory CS instructorsin the U.S. to investigate themes derived from theory and studies on adoption in higher education. Participants were selected using criteria to diversify the range of perspectives and experiences: rank and tenure statuses, teaching experience, gender, race, and institutional size, geographic location, populations served, public/private funding, etc. During our hour-long interviews, participants discussed their teaching and departmental contexts, their experiences of discovering and using various student- and instructor-centered approaches, their implicit theories of teaching and learning, and their attitudes toward and interactions with students, colleagues, and administration. Interviews and focus groups were recorded, transcribed, paired with classroom observation notes, and then coded and analyzed for emergent and hypotheses-driven themes. More details about our research methods are available in [1, 2].

3 QUALITATIVE RESULTS

Our principal research questions centered on how and why faculty find out about, try out, and routinely use new teaching practices, and how these processes are influenced by certain beliefs, experiences, and social interactions. In this paper, we address the research question: *why do CS faculty continue or discontinue using a new teaching practice?*

The most common reason why faculty continue or discontinue a practice is how it influences student learning and engagement—a finding also noted in other studies of faculty adoption [15]. If students participated and performed well, faculty continued to use the practice; if students did not seem to be learning and did not participate, faculty abandoned it. In some cases, engagement increased but not learning outcomes, or vice versa; when this happened, faculty made decisions based on which goal was more central to the reason they adopted. For example, one interviewee said of trying to flip his classroom, "The students in this class seem to really, really like it. But I'm worried that they're not learning as much so far. I worry about the discipline and concentration that they put into watching the videos. I don't think a lot of the students are mature enough to sit down and read a book, or watch a video and learn from it, sadly. It's too early to tell." To a large degree, faculty felt that students must do their part for their adoption to be successful.

Goals for use, and therefore what outcomes are used to inform their decision, are influenced by opinions about students and how they learn best (i.e., implicit theories of learning). For example, one faculty member at a large, public university said of his students, "I don't know if that happens [elsewhere], but it happens here, where kids are so lazy [that] they stop attending a class but they forget to go online and drop it." Getting students to come to class was a major accomplishment. Another interviewee said, "Students here tend to be very quiet, so I'm always trying to draw people out, to say things. I'm always working on trying to get them to contribute more. But, it doesn't happen often. I would like it to happen more often." Engaging students by getting them to pay attention and at times, struggle with concepts, was often explicitly or implicitly described as an essential component to student learning. Faculty sustained use when they perceived evidence of achieving these outcomes.

Faculty obtain data on student outcomes through a variety of means: comments made in class and during office hours, and from students' grades, attendance, attentiveness, participation, excitement, and engagement (explored in [1]). However, end-of-term course evaluations are the primary data source for many. "When I lectured and just blasted through things on overheads, course evaluations had a definite percentage of students that said, 'He's pretty boring.' And last semester in [the interactive] class, I had much less of that. There's something to having the students engaged." This statement, representative of many interviewees, speaks to two dimensions faculty care about: being thought of as an interesting or good educator, and being effective at engaging students.

For sustaining use, benefits to faculty were important, especially those related to making teaching easier, enjoying teaching more, or getting instantaneous feedback that allowed faculty to intervene when students struggled. One instructor at a state college described his reasons for continuing to use group work: "My experience team-teaching with [a colleague] led me to believe, you know, I *actually* enjoy this, a lot, just being a little bit freer and not being tied to thumbnails [i.e., lecture notes]."

Some faculty continued their use simply because the innovation took time and effort to implement. One faculty member described spending 6-8 hours per week building new slides and quizzes; once the infrastructure was laid in, there was no reason to abandon the new format, even when it did not have any discernible advantages over the lectures it replaced.

Instances of discontinuing were rare. One interviewee stopped using individual presentations because "[students] felt like it was just pure lecture by one single student and it was tough to keep focused. And when I did group-led classes, almost everybody said it was a good move. They loved it." Another gave up using peer code review, stating, "I don't have time. And when I do get time to do it, it doesn't seem to be very effective, which makes me less likely to do it well because it's precious class time. These were sort of half-hearted attempts in a sense that we tried it two times, three times in a semester. When it didn't seem to help them very much or they weren't forthcoming with their critiques of each other, I sort of take over." Experimentation on a limited basis is often argued to improve adoption [23], but because new instructional methods often increase students' metacognitive load, short term use can lead to student resistance (for example, see [19, 21]). When an innovative teaching method does not accomplish what it is supposed to do, faculty stop use.

Although not mentioned in our interviews, other research suggests that faculty may discontinue use of a practice when difficulties arise and there is not sufficient support and advice from champions or developers [15, 18]. Lack of interest from other faculty and department heads can also make it challenging to adopt or continue using a practice, or to convince departmental peers to support innovative teaching [20, 27].

4 SURVEY METHODS

Results from phase 1 provide testable insights as to how various outcomes, especially those related to student learning and engagement, comparatively influence sustained use. In phase 2, we examined the prevalence of these findings using a large sample of CS faculty in the United States.

4.1 Survey Construction and Design

Findings from phase 1 (including word choices used by faculty) informed the design of a survey instrument. To ground responses, faculty were asked to name a course, preferably one that students take earlier in the curriculum, and to provide an approximate enrollment and the frequency with which they used specific teaching practices in that class (reported in [16]). Faculty were then asked to report if they had tried using a new teaching practice in that course, and if so, what it was. Responses to this field, which we refer to as "innovations" (i.e., practices and tools that are new to the user [23]), were used to direct "yes" participants to a series of questions about how they became aware of it and what motivated them to first try it, what happened, do they keep using it, and why. Faculty who reported having not tried something were forwarded to questions on non-use. The survey was piloted among 10 CS educators from a large, public university. The revised survey was disseminated online.

4.2 Sample Development

Using U.S. Department of Education's Integrated Postsecondary Education Database System (IPEDS) [25], we created a list of institutions by type that awarded associate or bachelor's degrees in computer and information science in 2014 and 2015. We then used departmental websites to obtain contact emails for up to four faculty from each institution, focusing on identifying those who teach lower division courses in particular. Invitations were sent to a total of 4,088 faculty from 1,310 institutions.

4.3 Data Collection and Sample Characteristics

4.3.1. Data Collection. To increase the size and validity of the sample [7], potential respondents were emailed personalized invitations (e.g., Dear Professor <LastName>) that contained a brief message about the study and a link to a landing page where they could enter their email to receive a $20 gift card (or leave blank). Email addresses were logged separately from survey responses, with no way to match the data. Clicking "submit" on the incentive form forwarded participants to one of eight survey "collector groups" based on their institutional type.

4.3.2. Sample Size. The survey was administered in 2017 from May through July. 821 faculty completed at least part of the survey (response rate=20%). Incentive-to-survey settings prevent knowing the exact number of institutions sampled, but calculations per institutional type conservatively estimate that at least 595 U.S. colleges or universities are represented in the data.

4.3.3. Respondent Profile. To increase the representativeness of the sample, we staggered invitation send-outs per institutional type so that the final distribution of respondents would be proportional to the number of schools in each institutional type found in IPEDS. This distribution is reported in [16] and [17].

Respondent ranks were more or less evenly distributed among adjuncts and instructors (20%), assistant professors (25%), associate professors (25%), and full professors (27%). Another 3% wrote in that they were a chair or dean, or had no rank system. Tenure statuses were distributed among non-tenure track (21%), tenure-track (25%), and tenured (55%). Teaching experience ranged from 5 years or less (25%) to more than 20 years (26%), with 49% of respondents having 6 to 20 years of teaching experience. Twenty-two percent of the sample were women, 69% were men, and 8% described their gender as "not listed," "prefer not to respond," or opted to leave the question blank. Race/ethnicity was obtained through an open-ended question answered by 646 respondents: 81% were coded as White, 12% Asian, and 8% Black, Hispanic, Native/Indian, or other. We have been unable to find data for the population of CS faculty with which we could gauge our sample's representativeness.

5 SURVEY RESULTS

In total, 72% (n=584) of faculty reported that they tried a new teaching practice. After answering questions about how they found out about the innovation and what motivated them to try it (reported in [17]), faculty were asked to respond to questions about what occurred as a result of trying it regarding both general and student-related outcomes. Items and response frequencies are listed in Table 1. "Don't know/not applicable," auto-skipped, and non-response answers are excluded.

Most respondents, 85%, agreed that as their experience with using it increased, they were able to use it more effectively, and 73% agreed to some extent that the teaching practice took some trial and error. These findings suggest that the innovations faculty

Table 1: What Happened When Faculty Tried an Innovation

Outcomes from Initially Trying a Teaching Innovation		Strg Dis	Dis	Agr	Strg Agr
As I became more familiar with it, I was able to use it more effectively.	%	3%	12%	53%	33%
	N	14	63	279	175
My students were more engaged or interested.*	%	3%	13%	54%	30%
	N	17	69	286	159
My students had a better understanding of course content.*	%	3%	16%	55%	27%
	N	13	79	277	137
My students performed better.*	%	3%	20%	54%	23%
	N	15	95	263	112
My students developed better technical skills.*	%	5%	19%	53%	23%
	N	25	90	248	107
It took some trial and error to get it to work.	%	7%	20%	59%	14%
	N	37	107	320	78
My students expressed liking the course topic more.*	%	5%	23%	50%	22%
	N	22	97	216	93
It did exactly what I wanted it to do.	%	3%	27%	51%	18%
	N	15	149	278	100
Other faculty were interested in what happened when I used this practice.	%	15%	25%	48%	12%
	N	68	112	221	56
Teaching was easier after I started using this practice.	%	5%	35%	42%	18%
	N	27	178	217	91
My students expressed liking the major more.*	%	8%	33%	42%	18%
	N	27	114	146	63
It initially took a lot of time to set up.	%	11%	33%	34%	22%
	N	60	181	189	123
After the initial setup, it saved me time later.	%	9%	35%	40%	16%
	N	45	183	206	85
My students developed better social skills.*	%	15%	34%	40%	11%
	N	57	132	155	41
I found it difficult to implement.	%	15%	53%	26%	6%
	N	83	291	145	33
I was not able to cover as much material.	%	21%	52%	23%	4%
	N	110	276	125	23
My students told me in person they did not like it.*	%	42%	45%	11%	2%
	N	223	242	58	12
My students looked bored.*	%	35%	55%	7%	3%
	N	183	286	38	13
My end-of-term student course evaluations were more negative.*	%	35%	56%	7%	2%
	N	156	250	32	10
Class attendance decreased.*	%	33%	58%	6%	2%
	N	167	290	32	11

Notes: "Strg Dis"=Strongly Disagree; "Dis"=Disagree; "Agr"=Agree; "Strg Agr"=Strongly Agree, and "N "= Number of respondents. Items are listed in descending order by percent of total agreement (i.e., Agree + Strongly Agree).

Items without asterisks were prompted in the survey as, "Please reflect on what happened when you first tried the teaching practice '<piped text>.' To what extent do you agree or disagree with the following statements?"

Asterisks indicate the survey prompt asked, "To what extent do you agree or disagree that the following student outcomes occurred *as a result* of trying the teaching practice 'piped text'?"

selected were relatively complex, although it is unclear if they had—or needed—external support during implementation.

Regarding student outcomes, over three-fourths agreed that students were more engaged, developed a better understanding of content, performed better, and developed better technical skills. Engagement was strongly correlated with performance (*rho*=.69, *p*<.001) and understanding content (*rho*=.68, *p*<.001). Faculty mostly disagreed that negative student outcomes had resulted: around 90% disagreed that students said they did not like it, looked bored, that end-of-term course evaluations were more negative, or that class attendance decreased as a result of using the practice. A majority of faculty agreed that their students expressed liking the course topic more (72%) and liking the major more (60%) as a result of using the new practice. In general, these results indicate that most faculty believe their usage achieved positive outcomes for learning and engagement.

Faculty were then asked whether or not they still use the new teaching practice, using response options that also reflected the degree to which they have made changes to it since first trying it. 85% of respondents (n=483) reported still using it: of these, 20% had not made changes; 60% had made slight changes; and 20% had made substantial changes. 15% (n=83) of respondents said they no longer use their teaching practice. Thirty-two faculty left this survey item blank.

5.1 Why Faculty Continue Using Innovations

To determine what experiences and outcomes inform faculty decisions to sustain use, we used principal component analysis (PCA) to uncover underlying dimensions in faculty experiences of using their new teaching practice. PCA is recommended over factor analysis to identify underlying dimensions when data is exploratory [8], though extracted dimensions are usually identical and loadings are only marginally different [14]. We used Varimax rotation because it produces uncorrelated dimensions that reduce the risk of multicollinearity when scales are then used in regression analysis (which we do in this study).

Items representing negative experiences (e.g., "My students looked bored") were reverse coded for scale construction and reliability tests, so that higher scores in the resulting scale variables represent increasingly desirable outcomes. The analysis generated three dimensions, shown in scales 1 through 3 in Table 2. The underlying themes are as follows: (1) *benefits to students and the instructor*, (2) *student feedback*, and (3) *ease of use for the instructor*. Bolded values represent centrality to the dimension and were used to test Cronbach Alphas—all of which passed a minimum threshold based on the number of items [9]. Interestingly, the first and third dimensions correspond to two seminal elements—"perceived usefulness" and "perceived ease of use"—used in the Technology Acceptance Model (TAM) theory of adoption [5, 6]. Our scale variables therefore allow us to test if these constructs play an important role in sustaining use as well.

The first dimension, "benefits to students and the instructor," is so broad that it provides little analytical insight, so we attempted to disaggregate items into two sub-dimensions on theoretical grounds (supported by correlation coefficient clusters): benefits to students, and benefits to the instructor. Running additional PCAs to generate these scales, we found that benefits to students actually comprised two sub-dimensions: (1a) *benefits to student performance* and (1b) *benefits to improving student satisfaction in CS*, both of which had strong internal reliability. We ran an additional PCA to generate (1c) *usefulness to the instructor*. It may seem odd that "other faculty were interested" loaded in this last dimension, but theories of adoption typically consider visibility and boons to social prestige as components of "usefulness" [23]. Loadings and internal reliability for the three sub-dimensions of "benefits" are shown in the last three columns of Table 2.

Table 2: Scale Variable Creation for Outcomes Related to Sustaining Use, Principal Component Analysis Loadings

	SCALES					
SURVEY ITEM	**(1)**	**(2)**	**(3)**	**(1a)**	**(1b)**	**(1c)**
My students expressed liking the course topic more	**.83**	.11	.07	.40	**.87**	
My students expressed liking the major more	**.83**	.03	-.01	.32	**.91**	
My students were more engaged or interested	**.82**	.26	-.06	**.75**	.46	
My students performed better	**.81**	.34	-.10	**.90**	.30	
My students had a better understanding of course content	**.80**	.33	-.07	**.89**	.32	
My students developed better technical skills	**.78**	.17	-.01	**.66**	.51	
Teaching was easier after I started using this practice	**.71**	.21	-.09			**.85**
As I became more familiar with it, I was able to use it more effectively	**.66**	.12	-.18			**.75**
My students developed better social skills	**.65**	-.21	.13	(a)	(a)	(a)
It did exactly what I wanted it to do	**.62**	.45	.03			**.67**
After the initial setup, it saved me time later	**.56**	-.08	.00			**.66**
Other faculty were interested in what happened when I used this practice	**.49**	-.10	-.37			**.54**
My end-of-term student course evaluations were more negative	.12	**.79**	.12			
My students looked bored	.28	**.76**	-.11			
Class attendance decreased	.06	**.63**	.04			
My students told me in person they did not like it	.33	**.62**	.11			
I was not able to cover as much material	-.14	**.44**	.12			
It initially took a lot of time to set up	-.12	-.05	**.79**			
I found it difficult to implement	.25	.15	**.73**			
It took some trial and error to get it to work	-.14	.16	**.69**			
Cronbach's Alpha	.92	.73	.69	.90	.88	.73
Valid N	211	381	538	437	320	402
% of Variance Explained	33	14	10	48	37	49
Cumulative Var Expln.	33	47	57	48	85	49

Notes: Extraction Method: Principal Component Analysis, Varimax Rotation with Kaiser Normalization.
(a) "My students developed better social skills" was dropped from this scale because it lacks a strong theoretical tie-in. An alternative model (not displayed here) showed that this item would have had low loadings and a suppressing effect on the Cronbach's Alpha if it had been included in either scale.
Extracted Scale Labels:
(1): "Benefits to Students and the Instructor"
(2): "Student Feedback"
(3): "Ease of Use for the Instructor"
(1a): "Benefits: Student Performance"
(1b): "Benefits: Student Satisfaction in CS"
(1c): "Benefits: Usefulness for the Instructor"

We then ran logistic regression models on "continued use" ("no"=0, "yes"=1) to determine what impact each scale has on sustaining use. Results are presented in Table 3. Regression models are lettered (e.g., "A") to avoid confusion; numbers used in rows of independent variables correspond to those in Table 2. Coefficients are exponentiated betas; values greater than 1 signify an increase in odds (i.e., a positive effect), values less than 1 indicate a decrease (i.e., a suppressing effect). Model A includes the three scales from the initial PCA solution. Models B and C include disaggregated benefits to students, and to instructors, respectively. Model D shows a complete model of all predictors.

In the first model (A), the scale for achieving benefits to students and faculty—i.e., the overall "usefulness" of the innovation—has a substantial, positive effect on sustained use decisions. Confirming phase 1 results, faculty continued using a practice when it achieves desired outcomes. Disaggregating benefits in models B through D, we find that benefits to student performance have the largest effect on continuing use. Students' enjoyment of CS, while positive, is not statistically significant. Therefore, the decision to sustain use is informed specifically by the degree to which the teaching practice improves student performance, not how it improves student appreciation of CS.

In model C, when not controlling for benefits to students, usefulness to the instructor has a positive, significant effect on sustaining use. When student benefits are included in model D, statistical significance disappears and the effect becomes slightly negative. So, faculty decisions to sustain use are primarily guided by benefits to students, not by benefits to themselves.

As predicted from the qualitative data, the scale for student feedback is both statically significant and positive in model A, indicating that stronger disagreement that students gave negative feedback is positively related to sustaining use. However, in model D, this relationship disappears: the coefficient is only slightly above 1 and is not significant. Therefore, the role that student feedback plays is insignificant when compared to perceptions that the innovation is improving student outcomes. Student feedback may be only a small component of how faculty assess engagement and learning.

Table 3: What Influences Faculty to Continue Use?

Continued Use	Logistic Regression Models			
	(A)	(B)	(C)	(D)
(1) Benefits	5.09***			
(1a) s-performance		5.61***		6.11***
(1b) s-satisf in CS		1.70		1.80
(1c) i-usefulness			3.44***	0.89
(2) Student feedback	1.78*	1.03	1.44	1.03
(3) Ease of use	0.80	0.97	0.96	0.97
(Constant)	9.01***	11.29***	7.45***	11.40***
-2 Log likelihood	117.81	110.35	134.04	110.26
Cox & Snell R^2	0.27	0.30	0.20	0.30
Nagelkerke R^2	0.44	0.48	0.33	0.48

Notes: Significance levels: * p<.05, ** p<.01, *** p<.001
Values displayed in cells are exponentiated beta coefficients ("Exp(B)") and reflect the change in odds for a one-unit increase in an independent variable. Letters in parenthesis refer to regression models; numbers in parentheses refer to the extracted dimension listed in the headings of Table 2:
(1): "Benefits to Students and the Instructor"
(1a): "Benefits: Student Performance"
(1b): "Benefits: Student Satisfaction in CS"
(1c): "Benefits: Usefulness for the Instructor"
(2): "Student Feedback"
(3): "Ease of Use for the Instructor"
Dependent variable survey prompt: "Do you still use the teaching practice '<piped text>'?" (0="no," 1="yes")

Ease of use, which theory suggests is an important factor in the initial adoption decision [5, 6, 23], does not appear to matter in whether or not a CS instructor continues use. If anything, it has a slight suppressing impact that is not statistically significant when controlling for other considerations.

5.2 Why Faculty Stop Using an Innovation

The 83 respondents who said they no longer use their teaching practice were asked about the extent to which they agree or disagree that certain items influenced their decision. Shown in Table 4, the top consideration is that the innovation did not do what the faculty member wanted it to do (72% agreed), which typically related to improving student performance, learning, and/or engagement (as reported in [17]). 58% said that negative student reception played a role in discontinuing use, and 43% agreed they stopped use because it did not "fit" with other teaching approaches. Roughly one-third agreed that difficulties or time constraints played a role. Enrollment sizes, cost, departmental discouragement, and funding were not common problems, though these features would be more likely to prevent faculty from trying an innovation in the first place than to influence sustained use.

5.2.1. Failure Can Lead to Frustration. Participants were given an opportunity to provide any other reasons not listed in Table 4. Thirty-eight respondents wrote a response, of which four were difficult to interpret or concerned unrelated topics. The most common reason, mentioned by 21 respondents, concerned a perception that students had not made a good faith effort to participate. This was not only true for instructor-centered practices like using slides or video recordings ("Students were passive receptors and took no notes"), but also for many student-centered practices as well. In fact, perceptions that students had resisted or not done their part correlated, albeit weakly, with the practice being student-centered (*rho*=.30, p<.05).

Table 4: Faculty Reasons for Stopping Use of an Innovation

Reason for Discontinuing Use of an Innovation		Strg Dis.	Dis.	Agr.	Strg Agr.
It did not do what I wanted it to do.	%	12%	17%	36%	36%
	N	9	13	28	28
My students did not like it.	%	14%	28%	45%	13%
	N	11	21	34	10
It did not "fit" with my other teaching approach(es).	%	23%	34%	27%	16%
	N	18	26	21	12
It was too difficult to continue using.	%	29%	35%	27%	9%
	N	22	27	21	7
It took too much time.	%	29%	38%	22%	10%
	N	23	30	17	8
My class enrollment was too small for it to work well.	%	43%	43%	9%	4%
	N	32	32	7	3
My class enrollment was too large for it to work well.	%	42%	49%	4%	5%
	N	31	36	3	4
It cost too much.	%	57%	36%	4%	3%
	N	43	27	3	2
My department discouraged me from continuing with it.	%	58%	37%	5%	0%
	N	42	27	4	0
Funding for the project ended.	%	57%	41%	0%	2%
	N	32	23	0	1

Notes: Strg Dis.=Strongly Disagree; Dis.=Disagree; Agr.=Agree; Strg Agr.=Strongly Agree, and N=Number of respondents. Items are listed in descending order by percentage of total agreement (i.e., Agree + Strongly Agree). Survey prompt: "To what extent do you agree or disagree that the following influenced you to *stop using* the teaching practice '<piped text>'?"

In several cases, it seemed as if experiencing student passivity may have fostered a modicum of ill will. One faculty member wrote, "It did not work. Students don't want to discuss online. Students want to get in, get an A, get out. They don't care really about learning." Another faculty member who used active/cooperative learning reported, "The students did not want to participate. Some participated reluctantly. Others just refused to participate, and instead they spent the time reading their email or surfing the web or playing games until I began lecturing again. Afterwards the students criticized me for wasting class time." Another faculty member, who tried flipping their class said, "Students did not appear to be doing the necessary studying (examples, exercises, etc.) on their own (outside class), so I reasoned that bringing it into class would remedy that. Result: it did, but then they didn't do the reading that, in lieu of lectures, would introduce the material and give them the grounding needed to do the in-class work. There is an irreducible minimum that students must do. If they don't do their share, whichever part of teaching and learning that may be, no process or methodology can fix all the problems."

Yet another expressed frustration throughout several open-ended questions. "I tried using Kagan techniques one semester — it was an abysmal failure. I either didn't use the techniques well or the students were very resistant to anything different, probably a bit of both. Pairing students did not work well. I hoped that pairing students together would let them work together to learn and figure things out, but it did not. Either one strong student did nearly all of the work and the other did not, or both students struggled." In this case, the instructor felt responsible for the innovation not working out, but also acknowledged how students shared responsibility for the failure.

Six respondents said that the desired outcome, typically concerning student outcomes, was not achieved, but stopped short of faulting students. One respondent said that online discussions "did not engage students as I hoped it would," and another said of flipped classrooms: "It was awful. Tried it for three semesters. Test scores went down (somewhat) during those three semesters, despite me trying to 'patch up' the issues. Percent of people declaring a CS major went down. Test scores went up after I dropped it." Not achieving the desired outcomes resulted in abandoning the practice.

Other common reasons included the practice being too time-intensive (n=7), and experiencing infrastructure, cost, or technical problems (n=4). One faculty member described how using clickers created electromagnetic radiation that interfered with neighboring classrooms, and another said that live streaming "was a pain for my IT department and at that time, not all students had the bandwidth." In one instance, a faculty member said, "The course was taught by another member of faculty and now I need to co-ordinate material with them."

6 DISCUSSION AND IMPLICATIONS

In interviews, faculty strongly associated student engagement with learning. In our analysis, we found that both of these outcomes are so strongly correlated that we were unable to separate them from each other for testing. Across models, results show that benefits to student performance, comprising learning and engagement, are paramount for faculty to sustain their use.

What remains uncertain is the specific data that faculty consider, and how they obtain that data, in determining whether benefits to student performance have been achieved. Efforts to sustain use might be more effective if adopters are provisioned with feasible strategies and tools to conduct comparative testing (on students' grades, for example), and are encouraged to use them. If formal evidence is not used, faculty may infer or "feel" that students' learning or engagement is improving without using empirical evidence, which would violate the evidence-based, scientific nature needed for effective CS education.

In qualitative results, we found that faculty rely heavily on student feedback from a variety of clues [1], but in qualitative models, student feedback was not intrinsically related to assessing student performance (loading as a separate, uncorrelated PCA dimension), nor to continuing use (when controlling for student performance benefits). If the innovation achieves positive gains for students' performance, faculty are more likely to continue using it *regardless of student feedback*. We conclude that the impact of student feedback on sustaining use is more complicated than simply, "students didn't like it so I stopped using it"—although that does occur in a few cases. Student resistance, in the form of not making a good faith attempt to do what is required of them, leads faculty to stop using an innovation and in some instances, can even lead faculty to develop resentment toward students, which can negatively impact student engagement regardless of what pedagogy is used [11]. To reduce this resistance, faculty should consider communicating explicitly about why they are trying the new teaching method, how it works, and how it will help students directly. Committing to using it for an entire term may also help by lessening the metacognitive effort students have to put into learning how to learn. Short-term usage can create cognitive strain and introduce unpredictability, both of which lead to student resistance. Many students have been conditioned to expect non-interactive lecturing, and it takes intentional measures to break them of that prison of experience and expectation. For those wishing to encourage use of a new teaching practice that benefits learning and diversity, promoters may need to spend time to understand and address potential adopters' implicit attitudes toward students, and provide messages that the adopter can use to gain student buy-in.

Finally, although we started with a large sample, the number of respondents who stopped using their teaching practice was relatively small. These results give insight and direction for further research into the experiences and attitudes that lead to discontinuing use. Further study of faculty who have stopped using innovative practices would be highly beneficial to the CS education community.

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