Promoting instructional change in new faculty: An evaluation of the physics and astronomy new faculty workshop

Charles Henderson[a)]
Western Michigan University, 1903 W. Michigan Ave., Kalamazoo, Michigan, 49008

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An important finding of physics and astronomy education research (PAER) is that traditional, transmission-based instructional approaches are not effective in promoting meaningful student learning. Instead, PAER research suggests that physics and astronomy should be taught using more interactive instructional methods. These ways of teaching require significant changes in the way faculty think about teaching and learning and corresponding changes in their teaching behavior. Although the research base and corresponding pedagogies and strategies are well documented and widely available, widespread changes in physics and astronomy teaching at the college level has yet to occur. The Workshop for New Physics and Astronomy Faculty has been working to address this problem since 1996. This workshop, which is jointly administered by the American Association of Physics Teachers, the American Astronomical Society, and the American Physical Society, has attracted approximately 25% of all new physics and astronomy faculty each year to a four-day workshop designed to introduce new faculty to PAER-based instructional ideas and materials. This paper describes the impact of the Workshop as measured by surveys of Workshop participants and physics and astronomy department chairs. The results indicate that the Workshop is successful in meeting its goals and might be significantly contributing to the spread and acceptance of PAER-based instructional ideas and materials.
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I. INTRODUCTION

There are approximately 9000 full-time equivalent faculty at 797 degree-granting physics and astronomy departments in the United States.[1] Roughly 300 new faculty are hired each year by these departments into tenure-track positions at the assistant professor level.[1–4] These new faculty often have little preparation for their teaching roles and frequently struggle with their teaching responsibilities. An appropriately designed program has the potential to help new faculty in their teaching and promote the spread of instructional strategies and materials based on physics and astronomy education research (PAER).

The Workshop for New Physics and Astronomy Faculty (Workshop) is designed to be such a program. The Workshop brings together physics and astronomy faculty in their first few years of a tenure-track faculty appointment at a four-year college or university to a four day workshop at the American Center for Physics in College Park, MD. Typically, participants attend in the second or third year of their appointment after they have had at least one year of teaching experience. During the workshop participants are introduced to some of the basic findings of PAER and instructional strategies and materials based on these findings. Presentations are made by leading curriculum developers and PAER researchers. The Workshop is administered jointly by the American Association of Physics Teachers, the American Astronomical Society, and the American Physical Society with funding from the National Science Foundation.

The primary goals of the Workshop are to reach a large fraction of the physics and astronomy tenure-track faculty prior to their receiving tenure; help participants learn about recent developments in pedagogy and the assessment of changes in pedagogy; and have participants integrate workshop ideas and materials into their classrooms in a way that has a positive impact on their students and departments.

II. BACKGROUND

In the past few decades, PAER has produced many research-based instructional strategies and materials as well as evidence that these new strategies and materials can lead to significant improvements in student learning compared to more traditional, lecture-based instruction.[5] Despite the significant progress made by PAER, there is little evidence that PAER strategies or materials have been incorporated significantly into the typical introductory course.[6] The Workshop addresses this problem by introducing many new physics and astronomy faculty to these strategies and materials. Other groups have taken other approaches to address this problem. For example, the Project Kaleidoscope Faculty for the 21st Century project develops and nurtures a network of change agents within Science, Technology, Engineering, and Mathematics departments.[7] The Preparing Future Faculty program[8] and the Preparing Future Physics Faculty program[9] have focused on equipping graduate students with the knowledge and skills to be successful in all aspects of a faculty career.

One important theme in research on educational change is that, although change in teaching practices occurs by individual faculty members, disciplinary cultures have a significant, if not dominant, impact on faculty behavior.[10] Changing the way teaching is viewed within the physics and astronomy community may be the appropriate lever to bring about substantive change in the teaching practices of physics and astronomy faculty. The Workshop attempts to do so by introducing a substantial portion of new physics and astronomy faculty to the PAER knowledge base and the pedagogical strategies and materials that have been developed based on this research. Because the Workshop is run by three major disciplinary societies, there is an explicit endorsement of the importance of the Workshop.

One reason to develop a program especially for new faculty is that they have difficulty adapting to their role as teachers; a role for which they have not typically been well prepared. Many new physics and astronomy faculty have been teaching assistants in graduate school, but few have taught a course of their own before their first faculty position. Thus, the first few years of their first faculty position is a formative time in the development of an instructor's teaching style and is likely an ideal time for interventions aimed at promoting non-traditional instructional practices.[11]

An alternative view is that any departure from traditional instruction is dangerous because such non-traditional instruction may require more time than traditional instruction and result in lower student ratings—especially at first.[12] However, it is common for new faculty to spend much of their time on instructional activities and receive poor student ratings under normal conditions.[13–15] For example, Boice studied 77 new tenure-track faculty at two universities (one with a research emphasis and one with a teaching emphasis) via interviews and observations during their first year.[15] By the middle of their first semester, most of the new faculty reported that lecture preparation dominated their time. Few of the faculty reported teaching skill as depending on anything other than their knowledge of the content and clear, enthusiastic presentation. Most described their classes as standard facts-and-principles lecturing and many had no plans for improving their teaching. Most of these faculty received poor student evaluations of their teaching. Their typical reaction in light of these evaluations was to become better organized and to lower standards. These trends continued through all four semesters of the study. Boice concluded that new faculty typically teach cautiously, defensively, and tend to blame low student ratings on external factors such as poor students, heavy teaching loads, and invalid rating systems. He suggested that new faculty would benefit from programs that helped them find ways to increase student participation and avoid spending too much time on lecture preparation. Thus, one opportunity for supporting new faculty is to help them rethink their roles as teachers and help them use their teaching-related time more effectively.

Although workshop-based professional development is common, there is insufficient evidence to claim the effectiveness of this method.[12,16] In terms of learning theory, workshops tend to be transmission based and, therefore, just like transmission-based teaching, should not be expected to be highly effective. One review of the faculty development literature concludes that workshops and seminars "are unlikely to produce lasting changes in teacher behavior or lasting impact on students unless participants continue skill practice and receive critical feedback on their efforts."[17] A more recent review of professional development activities found that "faculty development benefits from making use of extended interventions, over a full semester, a year, or more."[18] Hence, there is reason to doubt whether a one-time, transmission-oriented workshop can be effective in achieving its goals of promoting instructional change in new faculty.

However, the Workshop for new Physics and Astronomy Faculty differs from typical professional development models in several significant ways: (1) The Workshop focuses only on new faculty unlike most professional development programs which includes faculty from a variety of ranks. (2) The Workshop further focuses on faculty from a single discipline (unlike most programs for new faculty which are institution run and include faculty from a variety of disciplines). (3) The Workshop presents a wide variety of pedagogical options unlike many discipline-based professional development workshops that focus on only a single instructional strategy. Henderson and Dancy have found that some faculty may be "turned off" by reformers who focus on a single strategy or set of materials.[19] Faculty see these reformers as selling a particular product and as promoting the idea that one type of instruction is appropriate for all faculty and in all situations.

As suggested by the literature reviews, one way that the Workshop might be effective is if it provides faculty with the motivation and initial knowledge sufficient to allow them to continue learning on their own after the workshop.

III. DESCRIPTION OF THE WORKSHOP

Attendees at the Workshop must be nominated by their department chair, and the only cost to the department is transportation to College Park, MD. The workshop runs from approximately 4 pm on a Thursday to noon the following Sunday and contains roughly 12 h of programming each day. Presentations and discussions include a mix of large group sessions and small group sessions. Table I provides an example of the types of sessions and presenters at a typical Workshop. It is important to note that the Workshop presenters are leading and well-respected curriculum developers since research suggests that the reputation of the reformer and/or their institution can have an important impact on how a reform message is received.[20]

During its first 11 years in operation, 759 faculty have participated in the Workshop, corresponding to approximately 25% of the number of assistant professor hires at degree-granting physics and astronomy departments in the U.S. during this time.[1–4]

The Workshop participants represent 344 distinct colleges and universities, which is 43% of the 797 degree-granting physics and astronomy departments in the U.S.[1] In addition, 170 departments have had more than one faculty member attend. Table II shows that faculty who attend the Workshop represent fairly well the population of physics and astronomy faculty with respect to the highest degree offered by their institution.

The NFW was funded with two grants from the National Science Foundation. The total award was approximately $1,000,000, of which $742,000 was spent during the first 11 years reported on in this paper.[21] This amount works out to a cost per participant of $978 (not including transportation costs to College Park).

IV. SURVEY

During spring 2007, a web survey was administered to all Workshop participants who could be located and who were still in academia. Of the 759 participants, 690 (91%) were still in academia and could be located. Of these, 527 completed the web survey before the beginning of the analysis. All responses to the open-ended questions are reproduced here verbatim from the survey. In addition to the post-workshop survey of former participants, 59 of the 77 Fall 2006 Workshop participants completed a pre-workshop web survey.

During spring 2007 a web survey was administered to all 794 U.S. physics and astronomy department chairs using an e-mail list provided by the American Institute of Physics.

Table I. Example of Workshop sessions. These sessions are from the Fall 2006 Workshop (listed in the order that they appeared in the program), and, with minor changes, are representative of all years. Large group sessions involve all participants at once. Small group sessions typically involve one-half or one-third of the participants. All sessions were scheduled for 1 or 2 h, with the majority being 1 h.

Large group sessions	Small group sessions
Research as a Guide to Improving Student Learning, Peter Shaffer and Lillian McDermott	*Peer Instruction*, Eric Mazur
How to Get Your Students to Prepare for Every Class, Evelyn Patterson	*Problem Solving*, Kenneth Heller
Active Learning and Interactive Lectures, Eric Mazur	*Digital Libraries*, Bruce Mason
Are You Really Teaching If No One Is Learning? Gauging the Success of Instruction Through Research, Edward Prather	*Astronomy,* Ed Prather and Gina Brissenden
The Physics IQ Test, Richard Berg	*Tenure and Promotion Issues*, Robert Hilborn and Steven Turley
Interactive Lecture Demonstrations, David Sokoloff and Ronald Thornton	*Supervising Undergraduate Research*, Robert Hilborn and Theodore Hodapp
Practical Advice from the Trenches – How to Survive Academia Without Giving Up Your Career, Your Family or Your Sanity, Diandra Leslie-Pelecky	*Supervising Graduate Students*
Making a Difference: Teaching for Retention, Jim Stith	*Physlets and Open Source Physics*, Wolfgang Christian and Mario Belloni
	Real Time Physics, Interactive Lecture Demonstrations, and the Physics Suite, David Sokoloff and Ronald Thornton
	Introductory Physics and Astronomy
	Upper Level Physics, Kenneth Krane
	Implementation at Research and Comprehensive Universities
	Implementation at Four-Year Colleges

The survey was completed by 206 department chairs. Approximately 53% of survey respondents reported having a faculty member from their department attend the Workshop. A more detailed description of the data collected and the full surveys used can be found in the evaluation report prepared by the author.[22]

V. RESULTS OF THE NEW FACULTY WORKSHOP

A. Knowledge and attitudes

Table III shows that nearly all (91.2%) of the participants would recommend the Workshop to a colleague in their department. Thus, participants appear to highly value their experience. Open-ended comments made by participants on the survey also show significant enthusiasm for the Workshop:

- "The payoff versus time commitment for this workshop was enormous!! I would insist that any new faculty member in our department attend one of these. I believe these workshops are having a large impact on the quality of college level physics teaching in the U.S."
- "The Workshop was absolutely the most useful meeting I've ever attended. I use ideas and methods I learned at the workshop every week. Each year, I incorporate more."

Table IV shows that most participants indicate familiarity with the specific PAER-based approaches discussed at the Workshop either as users, former users, or knowledgeable non-users.

Table V shows that participant knowledge and use of PAER-based assessment instruments appears to be much lower than their knowledge and use of PAER-based curricula. The lack of familiarity suggests that these instruments (with the exception of the Force Concept Inventory) were not featured prominently in the Workshop. The lack of use for those who are familiar suggests that participants might not see the value of using such instruments.

The data on knowledge and use of specific Workshop ideas presented so far have only been post-Workshop. It is possible that participants were already familiar with these ideas before attending. Prior to the Fall 2006 Workshop, baseline data were collected about participants' level of knowledge and use of these techniques. Table VI compares this baseline data to post-workshop data from 2006 participants who responded to the web survey of all former participants (administered approximately four months after the Fall 2006 Workshop). The largest changes shown on Table VI are in the levels of self-reported knowledge. For each technique

Table II. Institutional characteristics of Workshop attendees.

Highest physics and/or astronomy degree offered	Percentage of Workshop attendees	Percentage of physics and astronomy faculty at degree granting institutions (see Ref. 1).
None	1.5%	N/A
BA/BS	38.9	30%
MA/MS	5.5	10
Ph.D	54.0	60

Table III. Percentage of participants who highly recommend the Workshop.

Question 8. Would you recommend the New Faculty Workshop to a new colleague in your department?		
Yes	Yes—with reservations	No
91.2%	8.0%	0.8%

Table IV. Workshop participants' self-reported levels of knowledge about and use of specific PAER-based teaching techniques.

Question 17. Please rate the following:	I currently use it.	I have used it in the past.	I am familiar with it, but have never used it.	Little or no knowledge (I've heard the name, but do not know much else about it, or I have never heard of it).
Astronomy Tutorials[a]	8.7%	5.0%	30.2%	56.1%
Collaborative Learning	39.2	17.2	23.0	20.6
Cooperative Group Problem Solving	47.2	21.9	22.9	8.0
Interactive Lecture Demonstrations	46.1	24.2	23.4	6.3
Just-In-Time Teaching	22.9	18.0	50.9	8.2
Peer instruction	54.1	21.4	22.4	2.1
Realtime Physics	5.2	7.5	46.6	40.7
Personal Response Systems	32.6	15.0	43.7	8.7
Physlets	19.7	21.4	41.3	17.5
Tutorials in introductory Physics	13.1	20.9	45.8	20.3

[a]Reference 25.

presented at the Workshop there were large decreases in percentage of respondents who said that they had little or no knowledge of the technique. There are also increases in the self-reported use of all of the techniques, suggesting that these faculty made instructional changes as a result of the Workshop. It is possible that some of the increase is not due to changes in faculty behavior, but rather to a belief that their current or past teaching was consistent with the specific technique.

Table VII shows that 93.7% of the Workshop participants were interested in incorporating some of the workshop ideas into their teaching right after the workshop. This interest suggests that they had formed a positive opinion of the instructional techniques presented at the workshop.

B. Teaching behavior and student learning

Figure 1 shows participant responses to survey Questions No. 12 (rating of teaching style prior to the Workshop) and 13 (rating of current teaching style). The responses show that there was a large shift to more alternative teaching styles after the Workshop. Only 1% of participants rate their post-Workshop teaching style as highly traditional.

Figure 2 also shows that 70.7% of the participants rate their teaching style as more alternative than other faculty in their department, and 4.0% rate their teaching style as more traditional than other faculty in their department.

The department chair survey corroborates the participant self-report data. Figure 3 shows that 58.6% of department

Table V. Workshop participants' self-reported levels of knowledge about and use of PAER-based assessment instruments.

Question 18. Please rate the following:	I currently use it.	I have used it in the past.	I am familiar with it, but have never used it.	Little or no knowledge (I've heard the name, but do not know much else about it or I have never heard of it).
Astronomy Diagnostic Test (ADT)	3.2%	4.0%	25.9%	66.9%
Conceptual Survey in Electricity and Magnetism (CSEM)	8.2	6.5	30.3	55.0
Electric Circuit Concept Evaluation (ECCE)	2.2	2.8	26.1	69.0
Field-Tested Learning Assessment Guide (FLAG)	2.0	1.8	22.5	73.8
Force and Motion Concept Evaluation (FMCE)	4.5	9.7	33.4	52.4
Force Concept Inventory (FCI)	24.3	24.9	37.1	13.7
Mechanics Baseline Test (MBT)	3.9	9.4	41.6	45.1

Table VI. Workshop participants' self-reported pre-post gains in their knowledge about and use of specific PAER-based instructional strategies. (Summary of pre-post knowledge and use of specific instructional techniques for Fall 2006 Workshop participants. Pre-data represent 59 (77%) of the Fall 2006 participants. Post data represent 68 (88%) of the Fall 2006 participants. Cooperative Group Problem Solving was not included in the pre-survey, and the pre-survey did not distinguish between current and former users.)

Question 17. Please rate the following:	I currently use it or have used it in the past.		I am familiar with it, but have never used it.		Little or no knowledge (I've heard the name, but do not know much else about it or I have never heard of it.)	
	Pre	Post	Pre	Post	Pre	Post
Astronomy Tutorials	5%	13%	18%	49%	76%	37%
Collaborative Learning	17	43	17	37	66	21
Cooperative Group Problem Solving	N/A	56	N/A	35	N/A	9
Interactive Lecture Demonstrations	32	52	19	47	50	2
Just-In-Time Teaching	3	25	18	71	78	4
Peer Instruction	34	62	35	36	30	1
Realtime Physics	2	17	8	77	89	6
Personal Response Systems	21	32	28	55	51	13
Physlets	14	44	17	45	69	12
Tutorials in Introductory Physics	17	36	20	52	62	12

chairs rate Workshop participants as having a more alternative teaching style than other faculty in the department and only 2.9% of department chairs rate the participants as having a more traditional teaching style than other faculty in the department.

Figure 4 shows that 32.1% of participants report a "considerable" or "full" change in their teaching style since participating in the Workshop. An additional 64.4% reported some change in their teaching style. Only 3.5% reported no change in their teaching style. Figure 4 suggests a trend in larger reported changes in teaching the longer it has been since participation. One explanation for this trend emerged from the written comments made to survey Question No. 16 – see Table VIII for example comments. According to this explanation, the Workshop is a "gateway" experience that starts some participants on a larger process of exploration into alternative teaching methods. This explanation is consistent with the trend shown in Fig. 4 of more changes with teaching over time (because more exploration has taken place).

The data presented in Fig. 5 are also consistent with the explanation of the Workshop as a gateway experience. Figure 5 shows that participants rate the Workshop as a smaller contributor to their changes in teaching the more time that has elapsed since their participation. This result is consistent with the gateway theory because recent participants would have had less time to learn about other sources of information about alternative teaching strategies. Overall, 96.4% of participants who reported making a change in their teaching attribute at least some of this change to their participation in the Workshop.

Department chairs corroborate the participant self-report data. Table IX shows that 72.4% of the department chairs report that Workshop participants have made changes to their teaching as a result of their participation. It is reasonable that this percentage is smaller than the percentage of faculty who reported making a change in their teaching as a result of the Workshop because a department chair is unlikely to be aware of all the changes made in the teaching practices of faculty in their department.

Table X shows that 64.7% of participants believe that the Workshop has had a considerable or large positive impact on their students; only 1.3% say that the Workshop has not had a positive impact on their students. Table X also supports earlier claims that the Workshop introduces participants to new ideas about teaching and increases their motivation to work to improve their teaching. Table IX shows that 72.6%

Table VII. Interest of Workshop participants in trying PAER-based teaching techniques.

Question 11. Right after the New Faculty Workshop weekend were you interested in incorporating some of the workshop ideas into your teaching?	
Yes	93.7%
No	2.1
I don't recall	4.2

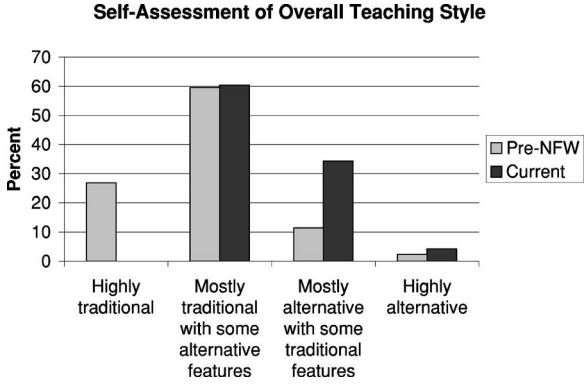

Fig. 1. Participant self-assessment of overall teaching style.

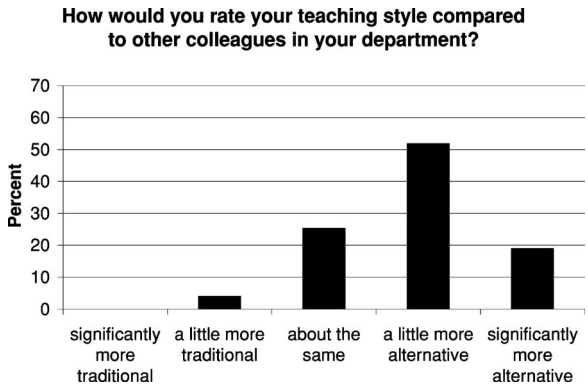

Fig. 2. Participant rating of their teaching style compared to other colleagues in their department.

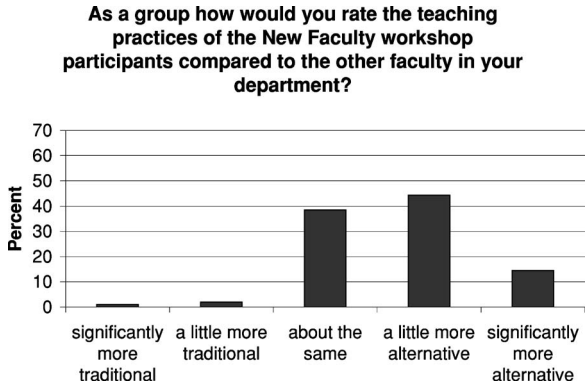

Fig. 3. Department chair rating of Workshop participant teaching style compared to other colleagues in their department.

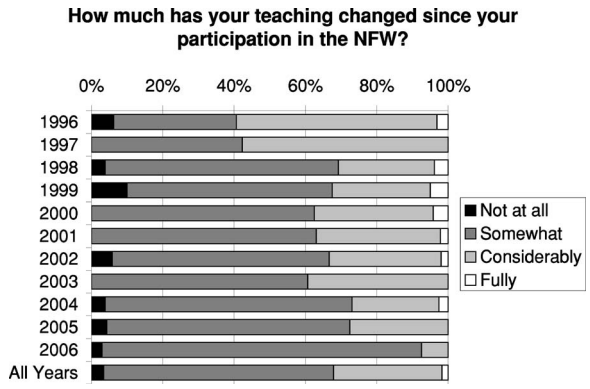

Fig. 4. Participant self-assessment of changes in their teaching since participation in the Workshop.

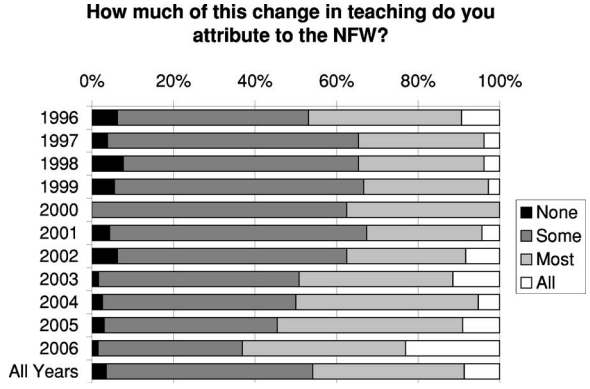

Fig. 5. Participant rating of the contribution of the Workshop to their instructional changes. (Data exclude 3.5% of respondents who reported no change in teaching since the Workshop.)

Table VIII. Participant descriptions of the Workshop as a gateway experience that started them on a larger process of exploration into alternative teaching practices. (Participants were asked to describe the impact that the New Faculty Workshop had on their teaching.)

• Although I only say that some of my teaching was altered by NFW, it provided an important seed, and in that sense has influenced much of what I've done. So the impact was large, though to be fair much of what I've done since involves what I have learned long after I attended NFW.
• Most important aspect of workshop was to wake me up to the fact that teaching matters, not just to my own tenure process, but it matters for our field to do a good job. That resonated with me, and I look back at that workshop as the moment when I really got that message. I've tried to incorporate some methods from it, but mostly I just try harder than I would have otherwise.
• Many factors contributed to my adoption of mostly nontraditional teaching styles, especially the influences of colleagues. The New Faculty Teaching Workshop was the true tipping point—I was primed, and this workshop created a true believer of me. Eric Mazur's talk and materials were key, and the wealth of good resources and supportive experts have been essential—especially Priscilla Laws' excellent workbooks and Ken Krane's leadership and personal encouragement.
• The new faculty workshop introduced me to a lot of ideas about teaching. It's biggest impact was to make me aware of teaching issues. It led me to later participate in many other teaching workshops.

Table IX. Responses of department chairs who have sent faculty to the Workshop on the impact of the Workshop.

	Yes	No
Question 10a. Of the faculty that have attended the New Faculty Workshop are you aware of any changes in their teaching as a result o the Workshop?	72.4%	27.6%
Question 11a. Do you believe that the students in classes taught by New Faculty Workshop participants are learning more or better as a result of the New Faculty Workshop?	72.6	27.4
Question 13a. Have the New Faculty Workshop participants had any influence on faculty in your department who have not attended the New Faculty Workshop?	51.0	49.0

of department chairs who have sent faculty to the Workshop indicate that it has led to improved student learning in classes taught by Workshop participants.

C. Departmental culture

Because one of the ultimate goals of the Workshop is to change the culture of physics and astronomy teaching in the U.S., it is not sufficient for participants to just learn about PAER-based instructional materials and strategies and make changes in their own teaching. They must also bring these ideas into their interactions with their colleagues in their home departments. There is evidence that these interactions have taken place. Table XI shows that 86.8% of the participants have discussed Workshop ideas with their colleagues. Based on their written descriptions, these discussions often occur when participants formally present what they have learned at a Workshop at a department colloquium or department faculty meeting. For example:

> "After the New Faculty Workshop, I presented a summary in a physics faculty meeting. As a result, a room was reconfigured with round tables and 2 senior professors attempted changes to their sections of introductory physics. Since then, we have also adopted Tutorials for our General Physics I and II courses. Alternative methods have been investigated and attempted by some faculty members. The majority of faculty members are moderately supportive of new teaching techniques, although some are resistant."

These discussions also often occurred as a result of pretenure teaching observations by colleagues. For example, "Obviously, all the faculty that came to evaluate my teaching discussed my use of JiTT [Just-In-Time Teaching] with me, but I also discussed with some other faculty. Now [they] are even adopting these ideas themselves—and not just the junior faculty."

Table XI shows that many Workshop participants (39.8%) report that their colleagues have made changes in their teaching as a result of these discussions. According to the written comments, many of these changes involved the use of personal response systems. For example, "With help from an older faculty member who had also investigated the idea, I taught the first course at my university using a personal response system. The technique has spread across campus, and just four years after my first test, our IT people have installed infrastructure into nearly every classroom on campus."

Table IX shows that 51.0% of department chairs also believe that Workshop attendees have influenced other faculty in the department. Table XII shows examples of the impact that department chairs report the Workshop has had on some departments.

VI. THE DANGER OF SELF-REPORTED DATA

Table IV shows that participants report high levels of use of one or more PAER-based instructional strategies. One danger of the use of self-report data is that a respondent may say that they are using a particular instructional strategy when an outside observer would think otherwise. One way to estimate the degree of over-reported use is to compare the general statements of instructional style made on Table IV

Table X. Response of participants on the impact of the Workshop.

Question 10. To what extent did your participation in the New Faculty Workshop…	Not at all	Somewhat	Considerably	Fully	Not Sure
Introduce you to new or more in-depth knowledge about teaching physics?	0.6%	16.9%	52.7%	29.0%	0.8%
Help you improve your skills in teaching?	1.5	35.9	47.3	11.8	3.5
Increase your motivation to work towards improving your teaching?	0.8	20.5	45.7	31.8	1.2
Have a positive impact on your students?	1.3	27.2	47.6	17.1	6.7

Table XI. Percentage of participants who report discussing Workshop ideas with their colleagues and percentage of colleagues that have made changes as a result of these discussions.

	Yes	No
Question 32. Have you discussed some ideas from the New Faculty Workshop with colleagues in your department?	86.8%	13.2%
Question 33. To the best of your knowledge, have any of your colleagues made changes in their teaching as a result of what you learned at the New Faculty Workshop?	39.8%	60.2%

with more detailed descriptions of instructional activities. In one part of the web survey, participants were asked to select a particular class that they had taught frequently since the Workshop and to identify the frequency with which they engaged in particular instructional activities. Table XIII shows the responses for the 192 participants (36.4%) who said that they used Peer Instruction[23] on Question No. 17 (Table IV) and also opted to report on the details of an introductory level class that they had taught. Only reports of instructional activities in introductory classes are used because Peer Instruction is primarily used at this level. Table XIII shows that these instructors report instructional patterns quite different from traditional instruction, which would rarely, if ever, involve students working on quantitative or qualitative problems or engage students in pair or small group discussions. But, to what extent are the reported instructional styles indicative of Peer Instruction?

Three of the instructional activities are particularly relevant for the non-traditional aspects of Peer Instruction: "Students solve/discuss qualitative problem." "Pair or small group discussion," and "Instructor questions answered simultaneously by entire class." In Peer Instruction each 1 h class session involves three or four lecture-ConcepTest segments.[23] During each segment the instructor first lectures on a particular topic. Students then work individually on a multiple-choice ConceptTest (a qualitative problem) followed by a pair or small group discussion with nearby students. Finally, the students simultaneously report on their answers using a show of hands, flash cards, or a classroom response system. Thus, we would expect faculty engaging in the "pure" form of Peer Instruction to report each of the three relevant activities occurring multiple times each class. This instructional pattern was reported by only19% of the subsample of 192 participants. If the criteria is loosened a bit to include faculty who report each of these three activities in "nearly every class," the percentage increases to 38%. Thus, only 19%–38% of faculty who say they are using Peer Instruction report instructional activities that are consistent with Peer Instruction. Some of this difference might arise because some instructors who teach differently in different classes might have chosen not to report on the class in which they use Peer Instruction. A more likely explanation for this difference, consistent with other available evidence, is that many of these faculty have not used Peer Instruction "as is," but rather have made significant changes based on some of the ideas of Peer Instruction.[24] Henderson and Dancy call this mode of operation reinvention and, in a small qualitative study, found that reinvention was the most common way that faculty made use of developed curricula.[19] There is not enough evidence in the survey data to judge whether the reinventions of Peer Instruction engaged in by Workshop participants are likely to be productive or not.

Table XII. Typical responses of department chairs who believe that Workshop attendees have had a positive impact on other faculty in the department.

Question 13a. Have the Workshop participants had any influence on faculty in your department who have not attended the Workshop? If yes, please explain.
• Our faculty are gradually adopting new teaching techniques and new faculty are leading the transition
• The enthusiasm and exposure to new ideas brought back by the faculty members who attended the workshops has spread throughout the department.
• They continually give pointers on how to improve others' classroom performances. It makes for great hallway and lunchtime conversations!
• Yes, most definitely. Every person in the department has adopted at least one teaching method introduced to our faculty attending the workshop.
• This influence may be more significant than the affect on the participants themselves. Two of our new faculty attended this year's workshop and at our January retreat they gave a presentation on the methods they learned at the workshop. Two of our tenured faculty (including myself) are now employing some of these techniques this semester.

VII. CONCLUSIONS

The evidence presented suggests that the Workshop for New Physics and Astronomy Faculty has been effective in meeting its goals of introducing new faculty to PAER-based ideas and materials and motivating faculty to try these ideas and materials. There is some evidence that Workshop participants have had an influence on other faculty in their departments. Thus, the Workshop appears to be contributing significantly to the spread of PAER ideas.

The Workshop appears to be able to introduce faculty to PAER-based instructional strategies and materials and to motivate many of them to continue to work on instructional improvement afterward. This study suggests that, at least under certain conditions, a one-time, transmission-based professional development program can be successful. The keys to the success of the program might be that it is sponsored and run by major disciplinary organizations, it introduces participants to a wide variety of PAER-based instructional strategies and materials, and presentations are made by the leading curriculum developers in PAER. Other disciplines might find it useful to implement similar disciplinary-based programs for new faculty. Such discipline-based models may also be appropriate for experienced faculty.

The one-time, transmission-based structure of the Workshop limits its effectiveness. According to the gateway theory, the primary reason for the effectiveness of the Workshop is that it provides participants with an overview of various instructional strategies and instills in them the motivation to learn more. Because many strategies are presented in a relatively short amount of time, participants often feel that they did not obtain enough understanding of the details of target instructional strategies. This participant desire for more details of particular instructional strategies, along with the variations in the implementation of Peer Instruction de-

Table XIII. Summary of self-described instructional activities of Workshop participants who are teaching an introductory course and indicated that they currently use Peer Instruction.

Question 22. During the most recent time you taught the course, over the semester or quarter, how frequently did/do you use the following teaching strategies during the lecture portion of your course?

	Never	Once or twice per semester	Several times per semester	Weekly	Nearly every class	Multiple times every class
Instructor presents theory	1%	2%	4%	28%	51%	15%
Instructor presents demonstration	2	4	23	32	31	9
Instructor solves/discusses quantitative problem	3	5	13	33	36	10
Instructor solves/discusses qualitative problem	4	2	10	25	37	24
Students solve/discuss quantitative problem	9	9	16	33	23	10
Students solve/discuss qualitative problem	3	1	12	25	33	27
Pair or small group discussion	4	2	15	24	25	30
Instructor questions answered simultaneously by entire class	8	2	8	15	26	40

scribed in Sec. VI, suggest that the Workshop might be enhanced by follow-up sessions or support focused on specific instructional strategies.

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[a]Electronic mail: charles.henderson@wmich.edu

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