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# Adapting to the Large-Scale Advanced Placement Chemistry Reform: An Examination of Teachers' Challenges and Instructional Practices

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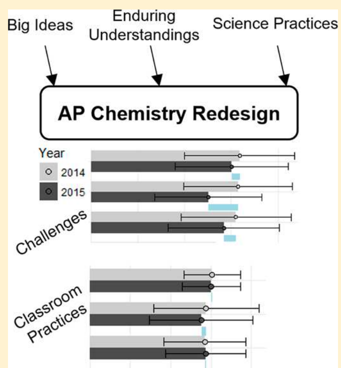
**ABSTRACT:** This quantitative study describes how teachers responded to the large-scale, top-down, mandated curriculum and examination reform of the Advanced Placement (AP) program in chemistry. This study analyzed data from a nationwide sample of teachers ($N$ = 1,062) teaching redesigned AP Chemistry courses in the first two years of the curriculum reform. Repeated measures analysis of covariance (RM-ANCOVA) indicated that teachers' perceived challenges about the AP redesign substantially decreased once they gained more experience teaching redesigned AP Chemistry courses. Teachers reported that inquiry laboratory investigations and changes in the AP examinations were the most challenging aspect of the curriculum reform, whereas the use of new textbooks and chemistry content was perceived as the least challenging. With respect to classroom practices, teachers more frequently enacted instructional elements directly related to the AP examination instead of incorporating references to core elements of the curriculum reform in their instruction. Similarly, though teachers reported frequently conducting laboratory investigations in their classrooms, only about 25% of the laboratory investigations included elements of student-generated inquiry, an important component of the redesigned AP Chemistry program. Surprisingly, teachers' self-reported classroom instruction remained similar in both the first year and the second year of the AP redesign. In general, this study suggests that school leaders and administrators should not be discouraged when teachers experience challenges during early phases of curriculum reforms. Adaptation to reform takes time. However, teachers may need special encouragement to adopt more in-depth aspects of curriculum reforms.




**KEYWORDS:** *High School/Introductory Chemistry, Chemical Education Research, Curriculum, Testing/Assessment, Professional Development, Quantitative Analysis*

**FEATURE:** Chemical Education Research

Revisions to high-stakes examinations are often viewed as strong incentives for corresponding changes in teachers' classroom instruction and student learning. In the United States, the College Board's Advanced Placement (AP) program in the sciences is an example of such a high-stakes examination because of its importance for students' college admission processes.[1,2] Generally, the AP program provides high school students with rigorous coursework in preparation for introductory college courses. Participation in AP programs is often regarded as a high-quality learning experience that leads to increased college enrollment, higher college grade point averages, and higher college graduation rates.[3−6]

There have been long-standing calls to reform advanced study in high school coursework to better prepare students for the high school−college transition and to equip students with the scientific knowledge and skills necessary for success in 21st century society.[7] Consequently, College Board responded to

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these recommendations with major design changes to the AP science program. The reform was implemented top-down, nationwide, and mandated for all AP Chemistry students and teachers. For chemistry, the first redesigned AP Chemistry classes were taught in the 2013−2014 school year. The first redesigned AP Chemistry examination was administered in spring 2014. Notably, the changes in the redesigned AP Chemistry program are similar to changes recommended by other national science standards such as the Framework for K−12 Science Education[8] and the Next Generation Science Standards.[9] As this large-scale reform required teachers to adapt to the curricular changes, this study examined teachers' perceived challenges with the reform, as well as changes to teachers' instructional practices during the first two years of the implementation of the AP Chemistry redesign.

## ■ BACKGROUND

### The AP Chemistry Redesign

The 2014 reform of the AP Chemistry program reduced its former emphasis on algorithmic procedures, rote learning, and memorization. The revised curriculum increased its focus on higher-order cognitive skills, deep understanding of science concepts, science practices, and inquiry learning.[10−12] Core elements of the revised AP Chemistry curriculum framework include "Big Ideas", "Enduring Understandings", and "Science Practices".[13] Ideally, teacher lesson plans and student activities in AP Chemistry classes should reflect these core curriculum features. For instance, laboratory investigations with student-generated inquiry provide prime opportunities to embed core elements of the revised AP Chemistry curriculum in classroom teaching.[11,14] The redesigned AP Chemistry examination also reflects these changes. Revisions to the examination included transformations of lower-order multiple-choice items to higher-order cognitive multiple-choice items (e.g., increasing context-dependent information in question stems, adding common misconceptions as distractors), content-based item redistributions (e.g., replacing algorithmically intense items [e.g., balancing equations, colligative properties, quantum numbers] with items allowing for stronger engagement with science practices [e.g., photoelectron spectroscopy]), and item format modifications (e.g., transforming multichoice questions to free and open response items).[10,11,15] Notably, the percentage of students receiving high grades ("4" and "5") on the AP Chemistry examination substantially dropped in the first year of the AP redesign and remained similar in the second year of the AP redesign performance compared to the last AP Chemistry examination prior to the curriculum reform (Table 1).[16−18]

**Table 1. Student Score Distribution Pre- and Post-AP Redesign**

| | Students Achieving a Given Overall Score, %, Relative to Year and Redesign | | |
|---|---|---|---|
| AP Chemistry Test Score | 2013: Pre-Redesign ($N$ = 140,006) | 2014: First Year Redesign ($N$ = 148,554) | 2015: Second Year Redesign ($N$ = 152,745) |
| 1 | 26.0 | 21.4 | 21.7 |
| 2 | 14.9 | 25.8 | 24.9 |
| 3 | 18.8 | 25.9 | 28.1 |
| 4 | 21.5 | 16.9 | 16.1 |
| 5 | 18.9 | 10.1 | 9.2 |

### Teacher Concerns about and Responses to Change

Implementations of top-down curriculum reforms in secondary education often vary in their consistency depending on the local school context, resulting in many local adaptations.[19,20] In reform implementation processes, teachers are often considered as important change agents and stakeholders for success.[21] Teacher knowledge, beliefs, and sense-making influence how curriculum reforms are perceived and implemented in classroom practice.[20,22,23] Teachers' perceptions of reforms often relate to their role in the reform process and how it affects themselves and their students, which can be described as concerns. These teacher concerns are traditionally grouped into four categories: (a) unconcerned (awareness of reform), (b) self (informational and personal concerns about reform), (c) task (management of reform), and (d) impact (consequence, collaboration, and refocusing with respect to the reform).[24−26] For instance, in early stages of the reform, teachers might have more concerns about the premises and procedural challenges of implementing new laboratory investigation in real-world contexts (e.g., acidity analyses during titration experiments) in their AP Chemistry class. Thus, teachers might focus more on the "mechanics" of the laboratory investigation than on ensuring that students engage with inquiry learning opportunities. However, teachers' concerns, and thus their impact on classroom practice, can change over time in a quasi-developmental progression.[25] As teachers become more familiar with the AP Chemistry redesign, their concerns might shift from "doing the lab right" to ensuring that the lab also "facilitates student thinking". Consequently, teachers might refocus, for example, the "molar volume of a gas" laboratory to include more elements of student-generated inquiry to increase the emphasis on core practices of the AP Chemistry redesign to move students' conceptual understanding of chemistry.

### Teacher Professional Development in Response to the AP Chemistry Redesign

Shifts in instructional classroom practices in response to curriculum reforms often require teachers to acquire new knowledge and skills and potentially change their existing attitudes or beliefs. Participation in professional development (PD) activities is often considered a prime opportunity for in-service teachers to engage in capacity building that enables knowledge and skill growth that lead to instructional changes, ultimately increasing student learning and achievement.[27−30] Decades of research on the impact of PD activities on teacher learning and instructional change identified several elements that constitute "high-quality" PD design characteristics such as active learning, focus on student work, coherence, duration, and collective participation.[27,31−34] However, empirical research that directly related PD participation to student success indicated mixed results as PD effectiveness is also dependent on a range of latent factors including the PD's underlying design in supporting teacher learning, teachers' microlevel interactions while engaging in PD-related activities, and potential misalignment of PD activities with teachers' ideas and beliefs, among others.[35−38] AP Chemistry teachers participated in a broad range of PD activities to prepare for the AP Chemistry reforms. Table 2 lists the most common PD activities AP Chemistry teachers participated in during the first and second year of the AP redesign implementation.[39] Almost all AP Chemistry teachers chose to engage in some forms of PD.[39] The most popular face-to-face PD activity was College


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Table 2. Comparative AP Chemistry Teacher Participation in Professional Development Activities

| Professional Development Activities by Type | Survey Respondents' Participation 2014 (N = 2389) | 2015 (N = 2195) |
|---|---|---|
| Face-to-Face Activities | | |
| AP Summer Institute[a] | 53.6 | 34.3 |
| AP Fall workshop[a] | 16.9 | 14.6 |
| Mentoring/coaching one-on-one or with other teachers | 15.2 | 19.6 |
| District/regional/local college/teacher-initiated meetings | 14.1 | 14.9 |
| Other face-to-face activities | 9.0 | 8.6 |
| Conferences or conference sessions | 7.8 | 8.2 |
| Transition to inquiry-based laboratories workshop[a] | 4.1 | 2.1 |
| Serving as an AP reader | No data | 3.5 |
| Serving as an AP consultant | No data | 1.3 |
| Self-Paced Online Courses | | |
| AP Central webcast: Exploring atomic structure using photoelectron spectroscopy[a] | 15.7 | 16.1 |
| Other self-paced online courses | 3.3 | 3.9 |
| Introduction to AP Chemistry[a] | 3.0 | 2.8 |
| Transition to inquiry-based laboratories[a] | 2.3 | 2.8 |
| Online Teacher Communities | | |
| College Board AP online teacher community[a] | 51.9 | 52.8 |
| National Science Teacher Association online teacher community | 7.3 | 9.1 |
| Other online teacher communities | 6.1 | 5.8 |
| Materials | | |
| AP course and exam description[a] | 95.6 | 91.7 |
| AP lab manual[a] | 84.6 | 74.4 |
| Instructional materials developed from colleagues | 70.1 | 72.3 |
| Textbook teacher guide and related materials | 69.3 | 73.2 |
| Video resources | 40.4 | 49.1 |
| Articles from magazines and journals | 30.2 | 35.5 |
| Other materials | 10.0 | 7.4 |
| Practice AP exams[a] | No data | 93.2 |
| Computer-based simulations (such as PhET) | No data | 66.1 |

[a]Professional development provided by the College Board.

Board's AP Summer Institute, an intensive 4−5 day training program offered in summers prior to the school year. It is notable that, for the most part, the College Board does not directly offer PD to teachers, instead enabling a broad range of other organizations to offer PD aligned with the curriculum and exam. A notable exception to this is an online community, where out of all online PD activities teachers most frequently engaged in College Board's online AP teacher community, a web-based portal and discussion forum that allows teachers to discuss instructional strategies, share resources, and network with each other. Furthermore, most AP Chemistry teachers used materials such as College Board's AP course and exam description, the AP lab manual, and practice AP exams in their preparations for the redesigned AP Chemistry curriculum.

Several research studies investigated teachers' PD participation, and their relationships with instructional practices and students' AP scores in the context of the AP science redesign. For instance, a study provided in-depth insights into an exemplary PD program that focused on inquiry-based instruction and their connections to the redesigned AP Chemistry curriuclum.[40] Another study provided an example of a PD offering that emphasized concept development aligned to the AP Chemistry curriculum framework.[41] Furthermore, another study examined chemistry teachers' professional learning within a community of practice.[42] Regarding associations of PD with student performance, teacher participation in College Board's AP online teacher community was found to have a positive, direct, and statistically significant association with students' AP science performance across disciplinary subject areas and years of the AP redesign implementation.[43] Similarly, a study that utilized a subgroup analysis approach focusing on schools that largely enroll students with low socioeconomic status identified significant associations of participation in unconventional PD activities (e.g., materials-based PD, district/regional/local college/teacher-initiated meetings, mentoring and coaching) and participation in PD activities that supported teaching redesigned AP courses with students' AP performance.[44] Upon investigation of these associations, PD participation characteristics were found to relate to the number of enacted laboratory investigations and teaching practice elements related to the redesigned AP curriculum.[30] Notably, this study also indicated that teachers' perceived challenges with the AP redesign related to elements of teachers' classroom practice.[30] While this prior research examined teachers' responses to the AP reform and highlighted the relationships of PD, teaching practices, perceived challenges, and student performance, none of these studies provided in-depth investigations of longitudinal aspects of teacher concerns, challenges, and instructional enactments.

### Research Questions

This study is situated in literature seeking to understand teachers' adaptations in response to curriculum reforms from a perspective of chemical education research. In particular, this longitudinal study expands the literature base on the challenges teachers experience during a curriculum reform, as well as how teachers adapt their instructional practices in response to the reform during the first and second year of implementation of the large-scale, top-down AP Chemistry curriculum reform. The research questions are as follows:

- Research question 1: What challenges did teachers experience during the implementation of the AP redesign?
- Research question 2: What reform-related classroom practices did teachers enact during the implementation of the AP redesign?
- Research question 3: How did one year of teaching experience with the redesigned AP curriculum change teachers' instructional enactments and perceived challenges?

## ■ METHODOLOGY

### Data Sources and Sample

This empirical study is connected to a large longitudinal National Science Foundation-funded research project (Award 1221861) that examines teachers' responses to the revised AP science program in chemistry, biology, and physics. Data used in this study is based on teacher responses to web-based surveys sent to all AP Chemistry teachers in the United States in May 2014 and 2015, unless teachers were placed on College Board's "do-not-contact" list. These surveys inquired about teachers' experiences with the revised AP Chemistry exam and


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| *In the current school year (201X-1X), the AP redesign may have posed challenges to your instruction. Please indicate below how much of a challenge each of the following elements of the AP redesign was for you.* | No challenge at all (1) | (2) | A moderate challenge (3) | (4) | A large challenge (5) |
|---|---|---|---|---|---|
| Chemistry content | ○ | ○ | ○ | ○ | ○ |
| The organization of Chemistry content | ○ | ○ | ○ | ○ | ○ |
| Labs | ○ | ○ | ○ | ○ | ○ |
| Inquiry Labs | ○ | ○ | ○ | ○ | ○ |
| Format of questions/problems/exam | ○ | ○ | ○ | ○ | ○ |
| Application of science practices to the content | ○ | ○ | ○ | ○ | ○ |
| Development of a new syllabus | ○ | ○ | ○ | ○ | ○ |
| Designing new student assessments | ○ | ○ | ○ | ○ | ○ |
| Using the textbook for the Chemistry AP redesign | ○ | ○ | ○ | ○ | ○ |
| Working with a new or different textbook | ○ | ○ | ○ | ○ | ○ |
| The pacing of my course | ○ | ○ | ○ | ○ | ○ |
| Moving my students to a conceptual understanding of Chemistry | ○ | ○ | ○ | ○ | ○ |

| *In the current school year (201X-1X), how often did you do each of the following in your AP Chemistry class?* | Never or only once /year (1) | Once / quarter (2) | Once / month (3) | Once / week (4) | Nearly every day (5) |
|---|---|---|---|---|---|
| Refer to the "Big Ideas" of Chemistry (as defined by the AP Chemistry course and exam description) | ○ | ○ | ○ | ○ | ○ |
| Use a science practice in your class outside of the laboratory | ○ | ○ | ○ | ○ | ○ |
| Have students work on laboratory investigations | ○ | ○ | ○ | ○ | ○ |
| Have students perform guided inquiry laboratory investigations | ○ | ○ | ○ | ○ | ○ |
| Provide guidance on test questions which integrate content and process (e.g., essential knowledge and science practices) | ○ | ○ | ○ | ○ | ○ |
| Provide guidance on test questions that are open/free response | ○ | ○ | ○ | ○ | ○ |
| Have students report laboratory findings to other students | ○ | ○ | ○ | ○ | ○ |
| Reference how enduring understandings relate to the "Big Ideas" of Chemistry | ○ | ○ | ○ | ○ | ○ |
| Refer to the Learning Objectives from the AP Chemistry curriculum in class | ○ | ○ | ○ | ○ | ○ |
| Refer to the Curriculum Framework | ○ | ○ | ○ | ○ | ○ |

Approximately how many lab investigations in total did your students complete in the current (201X-1X) school year?

- ❍ None
- ❍ 1 lab investigation
- ❍ 2 lab investigations
- ❍ …
- ❍ 30 lab investigations
- ❍ More than 30 lab investigations

Approximately how many of the completed lab investigations were from the AP Chemistry Lab Guide in the current (201X-1X) school year?

- ❍ None
- ❍ 1 lab investigation
- ❍ 2 lab investigations
- ❍ …
- ❍ 16 lab investigations

The labs in the AP Chemistry Lab Guide have a major section having to do with skills development and a final few pages that have to do with using those skills to perform a "student-generated" investigation. Of the labs you did from the guide, in how many did your students conduct a student-generated inquiry investigation in the current (201X-1X) school year?

- ❍ None
- ❍ 1 lab investigation
- ❍ 2 lab investigations
- ❍ …
- ❍ 16 lab investigations

**Figure 1.** Partial survey instrument.

curriculum. The surveys included questions regarding their perceived challenges and concerns with the AP redesign, self-reported teaching practices, school and classroom context, PD participations, and demographics, among others. An example survey that includes all questions of this survey instrument, not limited to this study, is available online.[45] The survey design was validated through feedback from an expert advisory board, and a pilot phase with selected AP teachers using cognitive interviews.[46] The cognitive interviews used a talk-aloud methodology to validate alignment of the intended meaning of each survey item with the corresponding teacher interpretations. Iterative repetitions of this process were conducted to reduce item ambiguity. The reliability of the survey items was verified through comparisons of item distributions across survey administrations.

In total, $N$ = 2,389 (33.66% response rate) AP Chemistry teachers responded to the survey in 2014 and $N$ = 2,195 (26.04% response rate) in 2015, respectively. This study used data from chemistry teachers who responded to both the 2014 and 2015 surveys, $N$ = 1,062. Almost all teachers in this sample (90%) are the only AP Chemistry teacher in their school. Most teachers were white (87%), followed by Asian (5%), Hispanic/Latino (3%), and African American (2%). More teachers were female (62%) than male (38%). Teachers had on average 15.9 years of high school science teaching experience and an average of 7.3 years of AP science teaching experience during


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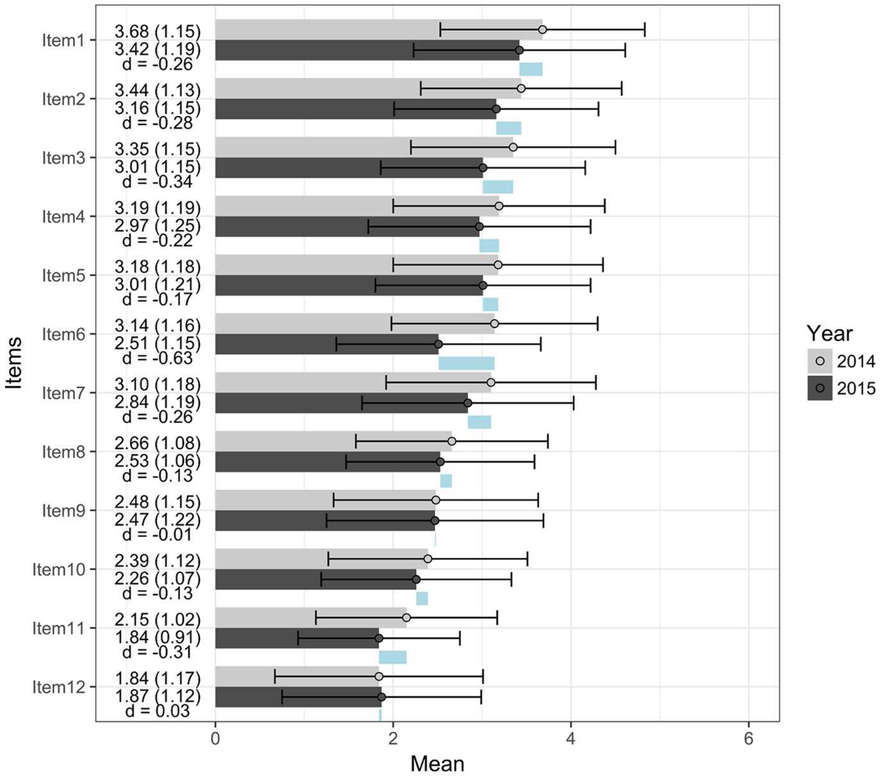


**Figure 2.** Plot of teachers' challenges with the AP Redesign; numbers describe mean and (standard deviation). Item1: Inquiry laboratory investigations. Item2: Designing new student assessments. Item3: Format of questions/problems/exam. Item4: Pacing of the course. Item5: Moving students to a conceptual understanding of chemistry. Item6: Development of a new syllabus. Item7: Laboratory investigation. Item8: Applications of science practices to the classroom. Item9: Using the textbook appropriately. Item10: Organization of chemistry content. Item11: Chemistry content. Item12: Working with a new or different textbook. $d$ = difference calculated as M15 − M14; $N$ = 1,062.

the first year of the AP Chemistry reform. Roughly 67% of teachers held a Master's degree, 18% a Bachelor's degree, 11% a doctoral degree, and 4% a Certificate of Advanced Study, respectively. Nonresponse analyses that applied nonparametric Mann−Whitey U tests indicated that teachers in this study taught in schools that had significantly higher average AP scores (2014, $z$ = 45.25, $p$ < 0.001, $r$ = 0.12; 2015, $z$ = 47.461, $p$ < 0.001, $r$ = 0.13), higher average PSAT scores (2014, $z$ = 25.48, $p$ < 0.001, $r$ = 0.08; 2015, $z$ = 26.66, $p$ < 0.001, $r$ = 0.08), and lower enrollment rates in free or reduced priced lunch programs (2014, $z$ = 6.74, $p$ < 0.001, $r$ = 0.08; 2015, $z$ = 7.41, $p$ < 0.001, $r$ = 0.09), compared to the overall AP Chemistry population. However, the effect sizes ($r \approx 0.1$) indicated that these differences can be interpreted as small effects.[47] Hence, the samples could be considered as a good representation of the overall AP Chemistry population.

## Analytical Methods

Prior to the statistical analysis, composite variables were computed to describe teachers' perceived administrative support and AP workload using exploratory and confirmatory factor analysis to generate Bartlett factor scores.[48] Identical to previous studies,[30,43,44] teachers' perceived administrative support composite included teacher responses to questions that inquired whether (a) the teachers' principal understands challenges for AP Chemistry students, (b) the principal understands challenges for AP Chemistry teachers, (c) the principal supports PD, (d) a lighter teaching load is offered, (e) fewer out-of-class responsibilities are assigned, (f) additional funding is provided, (g) sufficient equipment to perform laboratories is available, and (h) sufficient consumable/expendable supplies to perform laboratories are available. The AP workload composite included variables describing (a) teachers' numbers of students across all AP Chemistry sections, (b) teachers' numbers of AP Chemistry sections, and (c) teachers' numbers of weekly preps. Missing data was below 5% for each variable and assumed to be missing completely at random. This paper includes Supporting Information with the wording of all survey questions of the variables used as covariates in this study. Figure 1 lists the survey questions that were used as dependent and independent variables in this study.

The first research question was examined through descriptive analyses of teachers' responses to 5-point Likert-type scale items that asked teachers to rate 12 preselected challenges with the AP redesign. The second research question was examined through a descriptive analysis of teachers' responses to 5-point Likert-type items that inquired about 10 preselected instructional strategies related to the revisions of the AP Chemistry program, as well as three ordinal-response questions asking teachers how often they incorporated different types of laboratory investigations in their instruction (all laboratory investigations, laboratory investigations from College Board's AP Lab Manual, and laboratory investigations from College Board's AP Lab Manual with student-generated inquiry). The third research question applied repeated measures analysis of covariance (RM-ANCOVA) with the Huynh−Feldt correction to examine whether one year of teaching the redesigned AP Chemistry curriculum led to changes in teachers' self-reported instructional practices and perceived challenges with the AP redesign, comparing


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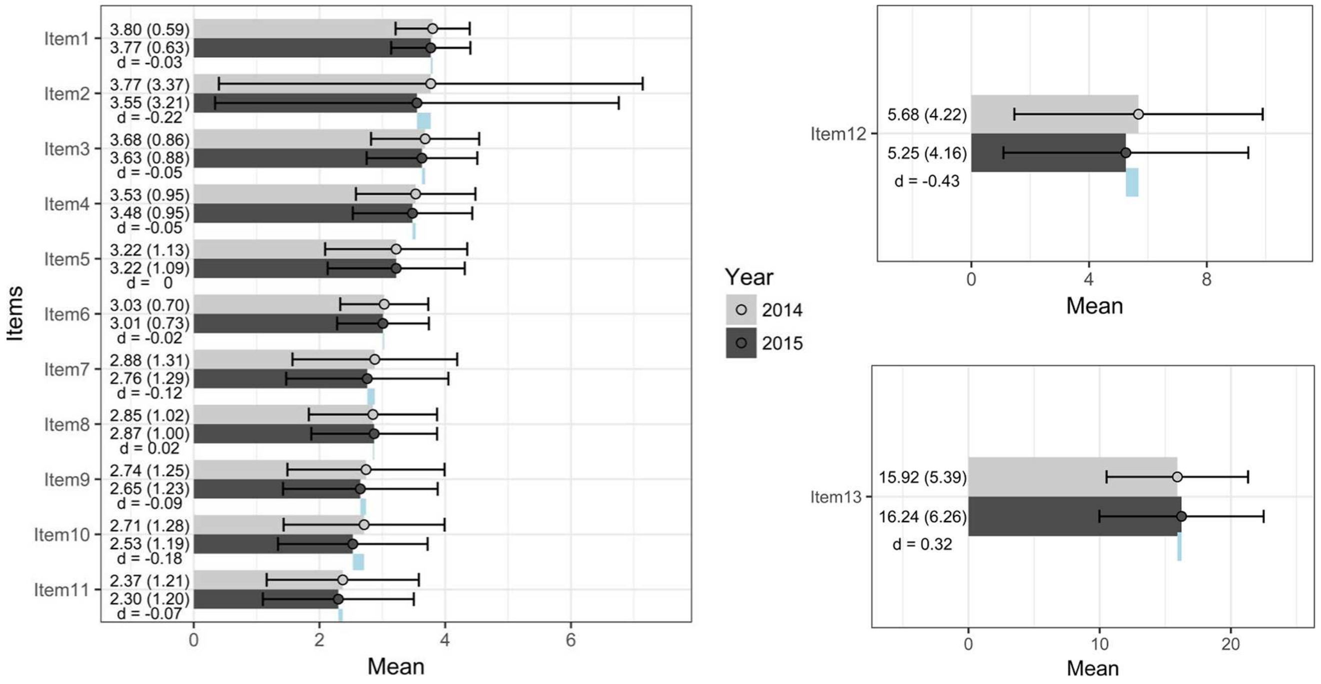


**Figure 3.** Plot of teachers' self-reported AP practice enactments; numbers describe mean and (standard deviation). Item1: Have students work on a laboratory investigation. Item2: Total number of laboratory investigations with student-generated inquiry. Item3: Provide guidance on test questions that are free and open response. Item4: Provide guidance on test questions that integrate content. Item5: Use a science practice in your class outside of the laboratory. Item6: Have students perform inquiry laboratory investigations. Item7: Refer to the learning objectives from the AP curriculum. Item8: Have students report laboratory findings to each other. Item9: Refer to "Big Ideas" of chemistry. Item10: Refer to the curriculum framework. Item11: Reference how the "Enduring Understandings" relate to the "Big Ideas". Item12: Total number of laboratory investigations from the AP Lab Manual. Item13: Total number of laboratory investigations. $d$ = difference calculated as M15 − M14; $N$ = 1,062.

responses from the 2015 and 2014 surveys. Control variables included teachers' gender, age, racial/ethnic background, degree level, out-of-field teaching status, perceived administrative support, and AP workload, as well as the percentage of students enrolled in free or reduced priced lunch programs.

A list-wise deletion missing data approach was applied separately for each model. Consequently, observations with missing data were only removed if the analytical model included a corresponding variable with missing data to maximize sample sizes across models. The models treated Likert-type scale and ordinal items (e.g., number of laboratory investigations) as quasi-continuous as differences between levels were assumed to be equidistant. To validate results, nonparametric Friedman tests were conducted as robustness checks.

## ■ RESULTS

### Teachers' Challenges with the AP Chemistry Redesign

A descriptive analysis examined teachers' ratings of perceived challenges on 12 preselected aspects of the AP curriculum reform (Figure 2). In the first and second year of the curriculum reform, the greatest challenge for teachers was the implementation of inquiry laboratory investigations in their instruction. Notably, teachers perceived aspects of guided inquiry during their enactment of laboratory investigation as challenging. Consequently, teachers rated laboratory investigations without inquiry components as considerably less challenging. Another area of challenge related to the format of the revised AP examinations. Teachers rated the design of assessments to prepare students for the revised AP examination as the second most challenging aspect of the AP redesign. Similarly, the format changes of questions, problems, and examinations through the AP reform were reported to pose the third highest challenges to teachers. In contrast, teachers did not perceive textbook and chemistry content-related aspects of the AP redesign as challenging. For instance, teachers perceived working with a new or different textbook as the least challenging aspect of the AP redesign. Similarly, teachers perceive the chemistry content and the organization of the chemistry content as the second and third least challenging aspects of the AP redesign, respectively.

### Teachers' Classroom Practices During the AP Chemistry Redesign

A descriptive analysis examined teachers' self-reported enactments of classroom practices related to the AP redesign (Figure 3). Out of the preselected AP practices, teachers were most frequently reported to incorporate laboratory investigations in their classroom practice. Additionally, teachers emphasized item-format-related aspects in their preparations to the revised AP examination. Providing guidance on free and open response test questions and integrated content test questions were the second and third most frequently self-reported enacted AP practices. Notably, core elements of the revised AP curriculum framework, such as referring to the "Big Ideas" or referencing how the "Enduring Understandings" relate to the "Big Ideas", were among the least frequently enacted practices in teachers' self-reports. Similarly, while teachers reported incorporation of a considerably high number of laboratory investigations in their classrooms, teachers' self-reported enactment on the number of laboratory investigations from College Board's AP Lab Manual or the number of laboratory investigations from College Board's AP Lab Manual


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Table 3. Results from RM-ANCOVA Examining the Influence of One Year of Experience with the Curriculum Reform on Teachers' Perceived Challenges with the AP Redesign and Self-Reported Instructional Practices

| Parameter | $N$ | $F$ | df (1, $x$) | $p$ | $\eta^2$ | Friedman Test | $p$ |
|---|---|---|---|---|---|---|---|
| Teachers' Perceived Challenges with the AP Redesign | | | | | | | |
| Development of a new syllabus[a] | 1885 | 211.74 | 888 | <0.001 | 0.193 | 130.925 | <0.001 |
| Format of questions/problems/exam[a] | 1884 | 76.88 | 887 | <0.001 | 0.080 | 50.968 | <0.001 |
| Chemistry content[a] | 1860 | 72.97 | 868 | <0.001 | 0.078 | 45.49 | <0.001 |
| Designing new student assessments[a] | 1879 | 57.95 | 883 | <0.001 | 0.062 | 32.207 | <0.001 |
| Inquiry laboratory investigations[a] | 1884 | 49.31 | 887 | <0.001 | 0.053 | 34.925 | <0.001 |
| Laboratory investigations[a] | 1885 | 39.39 | 888 | <0.001 | 0.042 | 29.233 | <0.001 |
| Pacing of the course[a] | 1883 | 28.11 | 886 | <0.001 | 0.031 | 13.786 | <0.001 |
| Moving students to a conceptual understanding of chemistry[a] | 1883 | 12.94 | 886 | 0.003 | 0.014 | 10.08 | 0.002 |
| Applications of science practices to the classroom[a] | 1882 | 8.73 | 885 | 0.003 | 0.010 | 8.199 | 0.004 |
| Organization of chemistry content[a] | 1880 | 8.65 | 883 | 0.003 | 0.010 | 3.692 | 0.055 |
| Using the textbook appropriately[a] | 1882 | 0.46 | 885 | 0.499 | 0.001 | 0.009 | 0.925 |
| Working with a new or different textbook[a] | 1791 | 0.11 | 808 | 0.738 | 0.000 | 0.027 | 0.869 |
| Teachers' Self-Reported Instructional Practices | | | | | | | |
| Refer to the curriculum framework[a] | 1875 | 10.37 | 879 | 0.001 | 0.012 | 6.066 | 0.014 |
| Total number of laboratory investigations[b] | 1881 | 4.72 | 885 | 0.030 | 0.005 | 1.509 | 0.219 |
| Total number of laboratory investigations from the AP lab manual[c] | 1880 | 4.60 | 884 | 0.032 | 0.005 | 7.337 | 0.007 |
| Refer to AP curriculum learning objectives[a] | 1879 | 2.84 | 883 | 0.092 | 0.003 | 3.004 | 0.083 |
| Refer to "Big Ideas" of chemistry[a] | 1878 | 2.02 | 882 | 0.156 | 0.002 | 2.384 | 0.123 |
| Guidance on free and open response questions[a] | 1879 | 1.72 | 884 | 0.191 | 0.002 | 1.357 | 0.244 |
| Have students work on laboratory investigations[a] | 1873 | 1.17 | 877 | 0.280 | 0.001 | 0.081 | 0.776 |
| Total number of laboratory investigations from the AP lab manual with student-generated inquiry[c] | 1864 | 1.17 | 870 | 0.279 | 0.001 | 0.101 | 0.751 |
| Reference how the "Enduring Understandings" relate to the "Big Ideas"[a] | 1877 | 1.01 | 881 | 0.315 | 0.001 | 0.955 | 0.328 |
| Students report laboratory findings to each other[a] | 1878 | 0.69 | 882 | 0.406 | 0.001 | 1.217 | 0.270 |
| Guidance on content integration questions[a] | 1876 | 0.25 | 881 | 0.616 | 0.000 | 0.841 | 0.359 |
| Use a science practice outside of the laboratory[a] | 1844 | 0.07 | 849 | 0.785 | 0.000 | 0.696 | 0.404 |
| Have students perform inquiry laboratories[a] | 1876 | 0.01 | 880 | 0.917 | 0.000 | 0.025 | 0.875 |

[a]These responses used a 1−5 Likert scale. [b]1−30 laboratories. [c]1−16 laboratories.

that included elements of student-generated inquiry were substantially lower.

## Influence of Experience with Curriculum Reform

Repeated measures ANCOVA indicated a decrease in teachers' perceived challenges with the AP redesign after gaining one year of experience teaching the redesigned AP course, controlling for a range of teacher- and school-level factors (Table 3). Most prominently, teachers' perceived challenge related to creating a new syllabus significantly decreased after one year of experience teaching the redesign course, representing a large effect ($\eta^2 > 0.14$).[49] Teachers' perceived challenges that significantly decreased with a medium effect size ($\eta^2 \approx 0.06$)[49] after one year of teaching experience with the revised curriculum included teachers' perceived challenges regarding format-related aspects of the curriculum reform (e.g., questions, problem statements, examination), the chemistry content, the design of new student assessments, and the implementation of inquiry laboratory investigations in classroom teaching.

Repeated measures ANCOVA did not detect significant differences for most self-reported teaching practices after one year of teaching experience with the redesigned curriculum (Table 3). All self-reported teaching practices, but the frequency of teachers' referencing of the curriculum framework in their AP Chemistry class did not significantly differ across years despite the high statistical power of the analysis given the large data set. However, teachers reported significant changes with medium effect sizes ($\eta^2 \approx 0.06$)[49] in the types of enacted laboratory investigations in their AP Chemistry courses after one year of teaching experience with the revised curriculum. While teachers reported to overall enact more laboratory investigations in their classroom, teachers incorporated fewer laboratory investigations from the AP Lab Manual in their teaching practice.

## Limitations

The main limitations of this study are related to the data sources. Threats to validity included that the data was limited to teacher self-reports on web-based surveys. As this study examined a reform with a nationwide scope, collecting additional data (e.g., classroom observations) was not feasible. Additionally, this study might suffer from a response bias as teachers who felt highly challenged by the reform might have stopped teaching AP after their first year. This bias is likely small as teachers' perceived challenges for teachers who responded to the surveys in both years are similar compared to teachers who only responded to the first year survey. Additionally, experiences with the AP redesign might differ for teachers whose students excelled on the exams prior to the AP redesign compared to teachers whose students were already challenged pre-AP redesign. Unfortunately, pre-AP redesign student-level data that would allow for such subgroup analyses was not available for this study. Also, treating Likert-type scale items as continuous variables assumes equidistance of the response categories. Additionally, some models violated parametric modeling assumptions such as approximate normality. However, robustness checks with the nonparametric


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Friedman tests were consistent with prior findings of the parametric models. Furthermore, generalizations to overall teacher populations need to be drawn with caution as AP teachers are likely the most qualified teachers in U.S high schools. For instance, in this study 82% of teachers held a Master's degree or higher, and 11% of teachers held a doctoral degree. Thus, this study could be viewed as a "best case" scenario with the most knowledgeable high school teachers in the United States who might be best prepared to respond to a curriculum reform.

## ■ DISCUSSION AND IMPLICATIONS

This study examined the large-scale top-down mandated nationwide curriculum and examination reform of the AP Chemistry program using a national data set with a good representation of the AP Chemistry population. The study explored teachers' classroom practices and perceived challenges during early stages of the implementation of the science reform. This study attempts to provide guidance for curriculum reformers, educational policy makers, and educational leaders when faced with large-scale changes in the educational landscape. Our data suggests three main findings and resulting implications for educational policy and practice.

First and foremost, teachers' classroom practices did not substantially change during the first two years of the reform adoption, as indicated by the results of the third research question. Notably, teachers did not modify their instructional enactments despite students receiving considerably worse AP Chemistry exam scores post-AP redesign compared to pre-AP redesign. In particular, the AP redesign introduced "Enduring Understandings" that capture core concepts of chemistry that are important for student learning and connected them to "Big Ideas" of Chemistry.[13] Consequently, both referencing "Big Ideas" and emphasizing their relationships to the "Enduring Understandings" can be viewed as key instructional practices aligned to the curriculum reform. Reasons why teachers might choose to not increase the emphasis on these practices in their instruction include that teachers might not perceive these practices as valuable in themselves or as helpful in improving student performance on the AP examination. Certainly, it is speculative that these specific changes would actually increase student scores although the curricular developers believe they would. Teachers might not feel prepared to change their instruction to incorporate these elements in their teaching, or given that AP teachers are often the more experienced and qualified teachers in a school, they may feel that their own approach is more suited to their situation and students. College Board and other PD providers should feel encouraged to devote more time to showing the value of these instructional practices, for instance, by demonstrating exemplary instruction or relationships to student growth during PD activities. Additionally, College Board might consider better alignment of test questions on the AP examination to these practices to make their importance for improved student learning more visible to teachers.

Second, teachers' classroom practices appeared to be more focused on teaching-to-the-test than on implementing integral aspects of the curriculum reform, as indicated by the results of the second research question. This could be good or bad depending on the quality of the test. The most frequently enacted instructional elements included preparations for the question format of the AP examination and the implementation of laboratory investigations. This emphasis on the summative assessment would be expected as high-stakes testing environments often lead teachers to align their instructional practices to external outcome measures.[50] In contrast, instructional activities that directly referenced core components of the redesigned AP Chemistry program (i.e., "Big Ideas", "Curriculum Framework", "Learning Objectives") were among the least frequently enacted teaching practices. Although teaching to a strong test, well-aligned with the curricular goals, could be a good practice, the emphasis on the item format expected on the AP examination rather than an emphasis on the core curricular elements suggests a more superficial focus. Despite the emphasis on laboratory investigations which was key to the reform of the curriculum, less than a fourth of the laboratory investigations included elements of student-generated inquiry. This suggests, as above, a more superficial implementation based on the structure of the reform rather than the substance. Consequently, reformers should incentivize teachers to implement more instructional elements that are more deeply related to the curriculum reform into their classroom practice. For instance, AP Chemistry teachers could be encouraged to align, or even replace, their laboratory investigations with the recommended laboratory investigations described in College Board's AP Lab Manual or other inquiry-oriented laboratory practices. Furthermore, if exam questions mirror practices illustrated in the AP Lab Manual, teachers might be more likely to adapt their students' laboratory experiences accordingly.

Third, teachers voiced more concerns about some aspects of the reform than others but felt overall less challenged after gaining experience with the new curriculum, as indicated by the results of the first and third research questions. The changes to the AP examination and the enactment of inquiry laboratory investigations were perceived as the greatest challenges to teachers. On the contrary, working with new teaching materials, such as a new textbook, as well as chemistry content knowledge were rated as the least challenging aspects of the AP Chemistry reform. College Board could have provided more information about the new AP assessments and items as part of preparation for the implementation of the reform. With that additional information, local support and PD opportunities could provide nuanced and targeted information, not only a general overview of the reform. The reduction of challenges is consistent with research that indicates changes in teacher concerns over time.[25] Therefore, those implementing curricular change should expect initial resistance and persist in their reform efforts despite challenges. It seems that this persistence would be most fruitful if the reform effort targets the teachers' nuanced views of the reform as suggested in point one. Additionally, the types of changes in teaching practices that the AP reform requires may take more time than two years and require much more support for teachers, for instance encouraging teachers to participate in effective PD activities. It might also be useful to make the argument for reform stronger and clearer to those conducting the implementation. While the AP redesign is mandatory with respect to adoption, other reforms might have opt-in/opt-out structures.

Overall, this study provides insights on chemistry teachers' responses to College Board's large-scale chemistry curriculum reform in U.S. high schools. The College Board is responsible for providing an examination that evaluates, as best as it can, the reforms in the AP Chemistry curriculum. The AP examination provides the College Board with a unique opportunity to ensure that teachers implement reform


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elements. However, if teachers do not perceive that the examination mirrors these reform elements or that implementation of reform elements in instructional practice yields higher scores on the AP examination, the College Board loses its unique opportunity in pushing for reform. Nonetheless, the true evaluation of the long-term impact of the AP Chemistry reform will require years of the cycle of teaching and reviewing AP examination results and iteratively changing teaching practice based on those scores. Future research, aside from a long-term longitudinal study, might examine how teacher, school leadership, and school characteristics influence teachers' perceived challenges with the redesign, for instance, focusing on teachers who felt the most challenged (or the least challenged) by the curriculum reform. Similarly, insights into the underlying reasons for teachers to adopt (or to not adopt) instructional practices related to the AP redesign and their relationships to student learning and performance would greatly benefit educational stakeholders. Ultimately, this research aims to support teachers to better prepare their students to succeed in their advanced high school science courses and subsequent college education.

## ■ ASSOCIATED CONTENT

### Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.8b00151.

Survey instrument (PDF, DOCX)

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### Notes

The views contained in this article are those of the authors, and not their institutions, the National Science Foundation, or the College Board.

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