Teaching Physics in High School Classrooms: What have we learned II?

Alliance for Physics Excellence (APEX)

Physics Teaching Research Program (PTR)

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APEX PTI Cohort 3 Summer PTI Workshop, June 5-16, 2017

Alliance for Physics Excellence

The goal of the *Alliance for Physics Excellence* (APEX) program is to 1) integrate research-based teaching practices into Alabama physics classrooms, 2) via in-service teacher education, and 3) evaluate the impact on physics teachers and their students in the state's school systems.

Framework for APEX Teaching and Learning (Part of APEX PCK)

I. <u>Know</u> the NGSS and state science learning goals and typical associated <u>learner preconceptions.</u>

II. <u>Engage students in dialogue</u> to allow and encourage them to fully express their initial and developing ideas related to investigating science phenomena, explaining events, and understanding conceptual ideas

III. <u>Conduct inquiry learning activities</u> in which students explore phenomena and ideas and model relationships with the goal of being able to interpret results and explain events.

IV. <u>Engage students in extension/elaboration activities</u> that prompt them to refine their initial thinking and to apply and extend the developed relationships and conceptual ideas in multiple contexts (Learning Cycle sequence).

Framework for APEX continued

V. Monitor student learning and refine instruction through ongoing formative assessment that informs next steps in instruction and provides actionable feedback to students to allow them to evaluate and modify their ideas and practices.

VI. Cultivate a classroom learning culture in which having ideas is valued, where learners share their ideas and use evidence and reasoning in being critical of ideas, while at the same time encouraging, being respectful to and supporting learners sharing their ideas.

VII. Use technology to support development and understanding of physics ideas

VIII. Participate in teaching as a professional inquiry through action research and collaboration.

APEX Cohort 3: Action Research Activity with Units to be completed during the Fall 2017 to Spring 2018 Academic Year

Complete at least 2 Action Research units next academic Year.

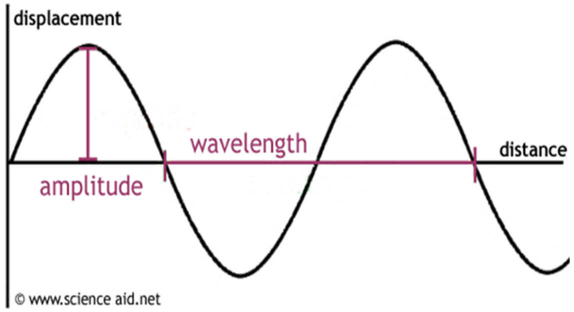
1) Force and Motion (FCI), 2) Electricity (CEEC) and 3) Waves (WSCT). Request pre and post test for the units before you start them. The needed components for each report include:

1. **Setting**
2. **Description of context** of the unit and instructional approach including **APEX strategies commonly used** in unit
3. **Example** of Daily Diary of **events** that occurred
4. **Pre and post FCI, CEEC, or WSCI, and Diagnoser Results**
5. **Interview with** your students – results and summary
6. Narrative reflective **summary** of the action research activity- **What did you learn? What was the evidence?**

Teaching Physics in High School Classrooms: What have we learned II?

During the April 7-8, 2017 weekend workshop we focused on what was learned through action research activities in our classrooms. Today we focus on

1. **What happened in our physics classrooms recently?**
2. **What was the impact of APEX changes made in our physics classrooms?**
3. **What did we learn?**
4. **How do we sustain, improve, and disseminate what we learned?**



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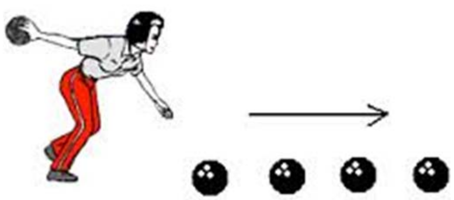
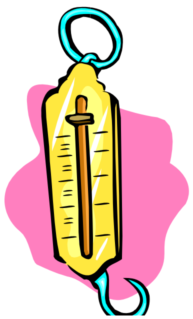
What happened in our physics classrooms recently?





Sequence of APEX Data Collection for Cohort 3

Year 0	Year 1	Year 2	Year 3
2014-15	2015-16	2016-17	2017-18

1) RTOP

Baseline		Mid	End

2) Student Achievement Measures (Act Res)

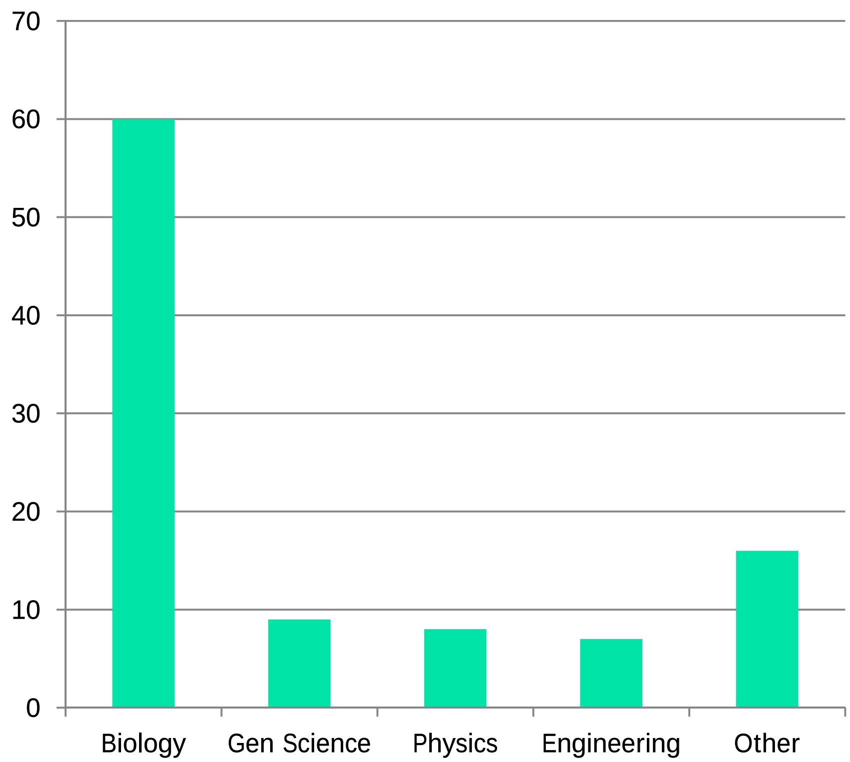
	1	2	3

Who was Teaching Physics in Alabama? Whole APEX

Baseline, Year 0 for all Cohorts 1, 2, 3

- Large Alabama representative sample of 75 schools and teachers from a statewide diverse, geographically large, population.
- Teaching experience: 1 – 37 years, average 11.5 years teaching science and 6.5 years teaching physics
- Male 39% and Female 61%
- Mean # physics courses taught per day = 2.4; 38.9% teach only 1 physics course.
- Students generally were underrepresented in science and attending high needs schools

Who was Teaching Physics?
Baseline, Year 0



Undergraduate College Major

- Biology = 61%
- General Science = 09%
- Physics = 08%
- Engineering = 07%
- Other = 16%

  (Earth Science, Math, Chemistry, other)

Teacher Perspective

Baseline, Year 0 - teacher interviews

Best way to teach physics

- Teacher interviews: different descriptions of "best teaching approach" =
  - Activities at desks
  - Discovery
  - Hands-on
  - Inquiry
  - Lecture
  - Solving problems
  - Teacher guided labs, etc.

Yet, observers' reported typical class involved

72% Lecture
20% Formal labs
8% Quizzes, Other

Observer Perspective
Baseline, Year 0 Cohort 3

Reformed Teaching Observation Protocol (RTOP)

Year	N	Min Score	Max Score	Mean	SE
0	32	22	97	46.63	2.53

65 = moderate level of classroom reform (innovation)

50 = presence of some reform characteristics

20= low level of reform, very traditional teaching

(*MacIsaac & Falconer, 2002)

Observer Perspective

Baseline, Year 0 Cohort 3

Reformed Teaching Observation Protocol (RTOP)

Observation Sub-score rating.   Maximum=20 each

Yr 0	Sub-score section
08.5	-Lesson Design & Implementation
13.4	-Propositional Knowledge
07.9	-Procedural Knowledge
09.1	-Communicative Interactions
09.9	-Student/Teacher Relationships

Observer Perspective
Baseline, Year 0 Cohorts 1, 2, 3

Reformed Teaching Observation Protocol (RTOP)

Year	N	Min Score	Max Score	Mean	SE
0	75	11.5	97	50.23	2.06

65 = moderate level of classroom reform (innovation)

50 = presence of some reform characteristics

20= low level of reform, very traditional teaching

(*MacIsaac & Falconer, 2002)

Observer Perspective
Baseline, Year 0 Cohorts 1, 2, 3

Reformed Teaching Observation Protocol (RTOP)

Observation Sub-score rating. Maximum=20 each

Yr 0	Sub-score section
08.9	-Lesson Design & Implementation
12.0	-Propositional Knowledge
08.9	-Procedural Knowledge
09.1	-Communicative Interactions
10.4	-Student/Teacher Relationships

Physics Teacher PCK

Baseline, Year 0

Pedagogical Content Knowledge -

Content Representation (CoRe) and Pedagogical and Professional experience Repertoires (PaP-ers)

Physics Teacher PCK Level*

Yr 0	PCK
04%	Advanced
28%	Proficient
67%	Novice or Emergent

(*Turner & Sunal, 2014)

Cross-Strand Integration

<u>Baseline</u> Year 0 conclusions found from teacher, student, and observer data

Conclusion 1: prevalence of expository teacher-centered approach for teaching physics

Conclusion 2: low level of understanding of inquiry teaching & learning as well as related assessment of active learning

Conclusion 3: use of general science teaching methods in physics - could not distinguish between methods used in teaching biology vs physics

Conclusion 4: report need for knowledge of physics & math

Conclusion 5: low awareness and use of student prior knowledge and implementing differentiated instruction

Conclusion 6: organized approach was not used when adopting reforms, e.g. classroom action research

Conclusion 7: teachers lacked collegial and mentor support experience in teaching physics

Cross-Strand Integration Summary

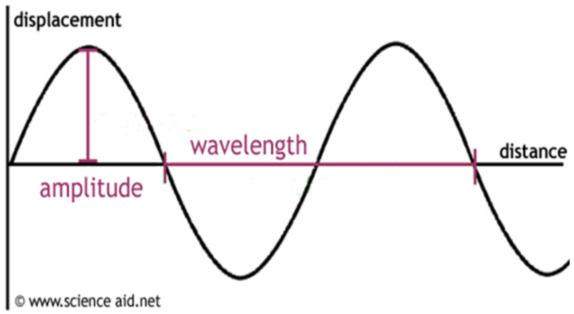
Baseline Year 0 conclusions found from teacher, student, and observer data

Five general and strongly interrelated themes emerged from the Year 0 needs assessment regarding

1) adequate physics and mathematics knowledge
2) knowledge of mathematical modeling
3) understanding inquiry teaching, learning, and assessment
4) understanding of importance and relevance of prior knowledge, formative assessment and feedback
5) professional confidence as a physics teacher.

APEX Professional Development Model: Teacher Knowledge Concepts

Year 1	Year 2	Year 3
• **Kinematics** • **Newton's Laws of Motion** • **Work, Energy, Power** • **Impulse & Momentum** • **Circular Motion & Rotation** • **Oscillations** • **CASTLE** • ***Prior Knowledge and Alternative Ideas*** • ***Effective Teaching Strategies*** • ***Learning Environments***	• **Fluid Mechanics** • **Temperature & Heat** • **Thermodynamics** • **Electrostatics** • **Conductors & Capacitors** • **Electric Circuits** • **Magnetic Fields** • ***Prior Knowledge and Alternative Ideas*** • ***Feedback & Metacognition*** • ***Collaborative Learning*** • ***Effective Teaching Strategies***	• **Electromagnetism** • **Waves** • **Sound** • **Geometrical Optics** • **Physical Optics** • **Atomic Physics** • **Nuclear Physics** • ***Prior Knowledge*** • ***Formative Assessment*** • ***Constructivist Epistemology*** • ***Effective Teaching Strategies***



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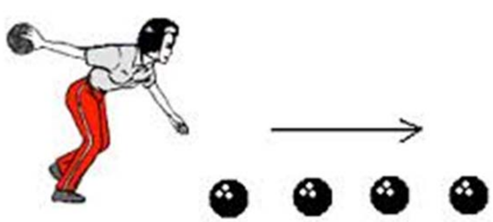
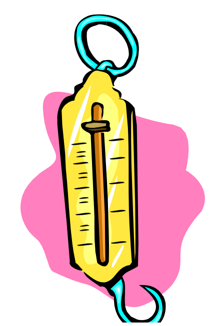
What was the impact of APEX changes in our physics classrooms?





Observer Perspective

RTOP Rating- Mid (Year 2) Cohorts 3 (part)

Reformed Teaching Observation Protocol (RTOP)

Year	N	Min Score	Max Score	Mean	SE
0	18	29.5	97	48.92	5.93
2	18	36.5	91	67.97	4.92

Significant difference between overall RTOP scores between Year 0 and Year 2, ANOVA $F = 18.67$, $\alpha < .01$

Observer Perspective

RTOP Rating-Mid (Year 2) Cohorts 3 (part)

Reformed Teaching Observation Protocol (RTOP)

Observation Sub-score rating. Maximum=20 each

Yr0	Yr2	Sub-score section
09.3	13.1	-Lesson Design & Implementation*
11.6	15.1	-Propositional Knowledge*
08.2	11.6	-Procedural Knowledge*
10.0	13.1	-Communicative Interactions*
10.7	14.6	-Student/Teacher Relationships*

Observer Perspective

RTOP Rating- Mid (Year 2) Cohorts 1-3 (part)

Reformed Teaching Observation Protocol (RTOP)

Year	N	Min Score	Max Score	Mean	SE
0	50	11.5	97	50.23	2.74
2	50	28	94.5	65.19	2.72

Significant difference between overall RTOP scores between Year 0 and Year 2,

ANOVA $F(1,93) = 12.28$, $\alpha < .01$

Observer Perspective

RTOP Rating-Mid (Year 2) Cohorts 1-3 (part)

Reformed Teaching Observation Protocol (RTOP)

Observation Sub-score rating. Maximum=20 each

Yr0	Yr2	Sub-score section
09.3	12.4	-Lesson Design & Implementation*
12.6	14.2	-Propositional Knowledge
09.5	11.9	-Procedural Knowledge*
09.5	12.7	-Communicative Interactions*
10.8	13.4	-Student/Teacher Relationships*

Observer Perspective - PCK
APEX Year 0 & 2 Cohorts 1-3 (part)

Pedagogical Content Knowledge -

Content Representation (CoRe) and Pedagogical and Professional experience Repertoires (PaP-ers)

Physics Teacher PCK Level*

Yr0	Yr2	PCK
08%	38%	Advanced
25%	35%	Proficient
67%	25%	Novice or Emergent

* Turner & Sunal, 2014

Observer Perspective

RTOP Rating– End (Year 3) Cohorts 1-2(part)

Reformed Teaching Observation Protocol (RTOP)

Year	N	Min Score	Max Score	Mean	SE
0	22	11.5	97	51.2	6.90
2	22	28	94.5	64.6	5.10
3	22	38.5	94	71.8	4.41

Significant difference between overall RTOP scores between Year 0, Year 2, Year 3

ANOVA $F(2, 41) = 4.1$, $\alpha = .018$

Observer Perspective

APEX Year 0, 2, & 3 End (Year 3) Cohorts 1-2(part)

Reformed Teaching Observation Protocol (RTOP)

Observation Sub-score rating. Maximum=20 each

Yr0	Yr2	Yr3	
08.5	12.4	14.2	-Lesson Design & Implementation*
13.1	14.3	15.9	-Propositional Knowledge*
09.5	12.5	13.5	-Procedural Knowledge
08.7	13.6	14.2	-Communicative Interactions*
10.2	13.1	14.2	-Student/Teacher Relationships*

*sig at < 0.05 level

Observer Perspective - APEX Cohorts 1-2 (part), Year 0, 2, 3

Reformed Teaching Observation Protocol (RTOP)

Observation Sub-score rating. Maximum=20

Yr0	Yr2	Yr3	
08.5	12.4	14.2	-*Lesson Design & Implementation**

This section focuses on lesson strategies respecting students prior knowledge, creating a learning community, and allow for student exploration and investigation with ideas originating with students.

Observer Perspective -
APEX Cohorts 1-2 (part), Year 0, 2 & 3

Reformed Teaching Observation Protocol (RTOP)

Observation Sub-score rating.   Maximum=20

Yr0	**Yr2**	**Yr3**	
13.1	14.3	15.9	-*Propositional Knowledge**

Knowledge can be thought of as having two forms: knowledge of what is (Propositional Knowledge), and knowledge of how to (Procedural Knowledge). This section focuses on the level of significance and abstraction of the content, the teacher's understanding of it, and the connections made with other disciplines and with real life.

Observer Perspective - APEX Cohorts 1-2 (part), Year 0, 2 & 3

Reformed Teaching Observation Protocol (RTOP)

Observation Sub-score rating.   Maximum=20

Yr0	Yr2	Yr3	
09.5	12.5	13.5	-*Procedural Knowledge*

This section focuses on the kinds of processes that students are asked to use to manipulate information, arrive at conclusions, and evaluate knowledge claims. It most closely resembles what is often referred to as scientific reasoning or mathematical thinking.

Observer Perspective - APEX Cohorts 1-2 (part), Year 0, 2 & 3

Reformed Teaching Observation Protocol (RTOP)

Observation Sub-score rating.   Maximum=20

Yr0	**Yr2**	**Yr3**
08.7	13.6	14.2 -*Communicative Interactions**

Classroom culture is conceptualized as: (1) Communicative Interactions, and (2) Student/Teacher Relationships. Communicative interactions in a classroom are an important window into the classroom culture. Lessons where teachers speak and students listen are not reformed. The nature of the communication captures the dynamics of knowledge construction in that community.

Observer Perspective - APEX Cohorts 1-2 (part), Year 0, 2 & 3

Reformed Teaching Observation Protocol (RTOP)

Observation Sub-score rating.   Maximum=20

Yr0	**Yr2**	**Yr3**	
10.2	13.1	14.2	-*Student/Teacher Relationships**

This section implies more than just a classroom full of active students. It also connotes their having a voice in how that learning activity is to occur. Active participation implies agenda-setting as well as student "minds-on" and "hands-on" inquiry using scientific and mathematical reasoning. A reformed teacher actively encourages this transition.

Perspective - PCK
APEX Year 0, 2, & 3 End (Year 3) Cohorts 1-2(part)

Pedagogical Content Knowledge -

Content Representation (CoRe) and Pedagogical and Professional experience Repertoires (PaP-ers)

Physics PCK Level*

Y0	Yr2	Yr3	PCK
08%	38%	71%	Advanced
25%	35%	14%	Proficient
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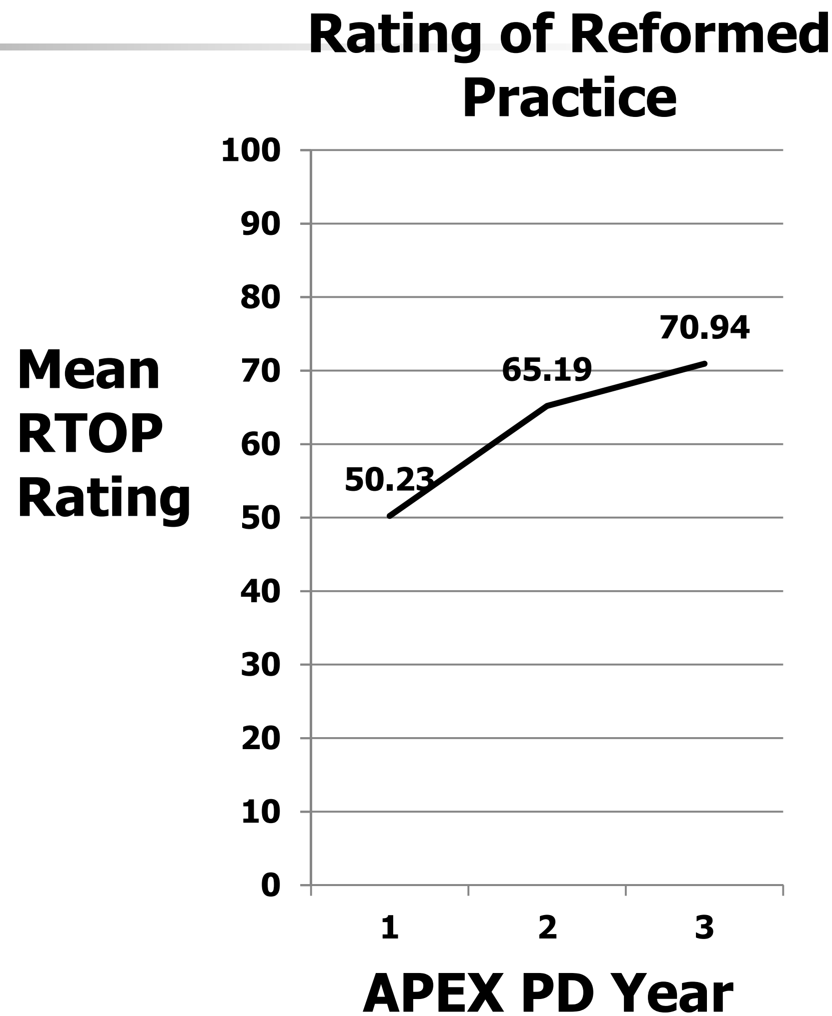
* Turner & Sunal, 2014

Year vs RTOP Summary

Key outcomes for physics focused professional development are:

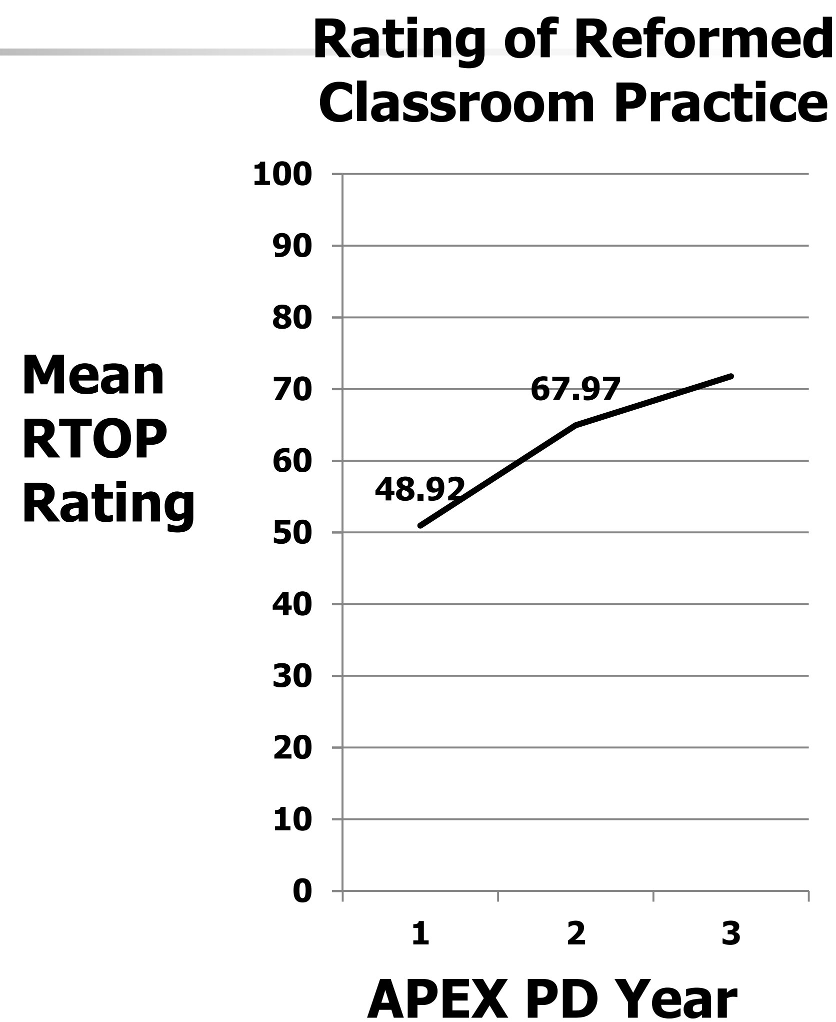
1) Using classroom data, teachers were rated by outside observers as having significantly **higher reformed practice (RTOP rating) with each year of PD** and classroom implementation (Effect size = 0.48)



Cohort 3-Year vs RTOP Summary

Key outcomes for physics focused professional development are:

1) Using classroom data, teachers were rated by outside observers as having significantly **higher reformed practice (RTOP rating) with each year of PD** and classroom implementation (Effect size = 0.49)



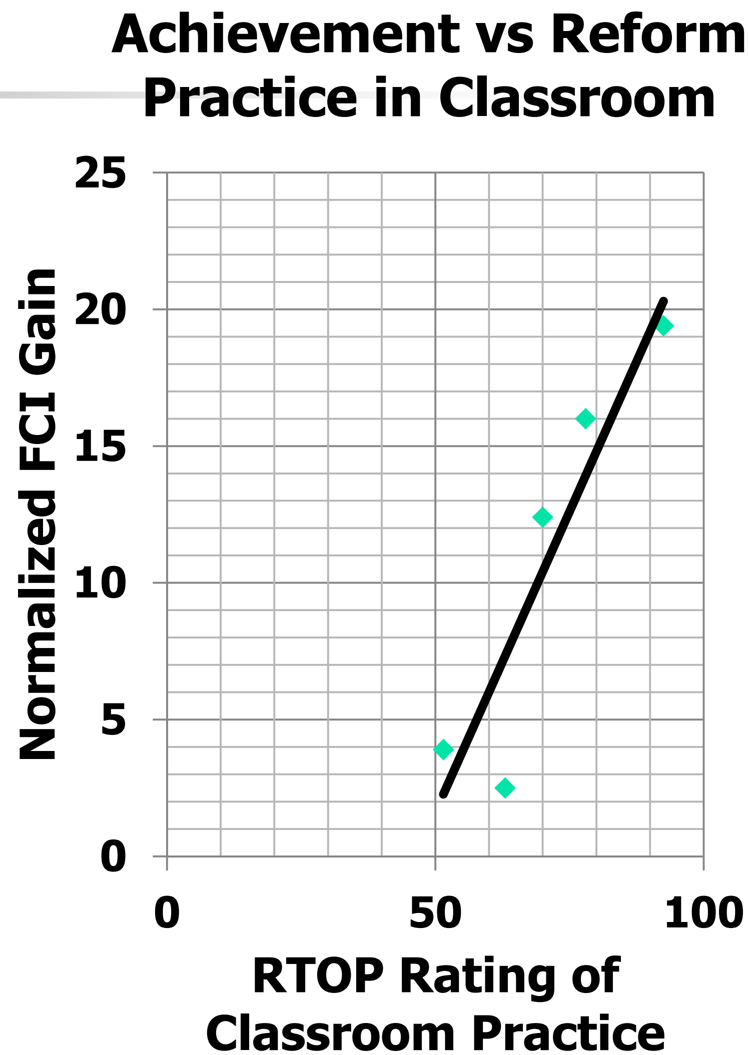
FCI Summary

Instrument	Mean	SD	Range	Min/Max Score
FCI Pre test	24.65%	14.88	20-67	1-100%
FCI Post-test	46.91%*	23.65	24-84	1-100%

RTOP vs FCI Summary

2) For sample of APEX Year 2 teachers, **student achievement gains were related to RTOP rating of classroom practice**.

Pre-post tests from teachers' Force & Motion Unit used to calculate an FCI Normalized score gain. Sample RTOP ratings; Mean=65, Range=51-92 compared with FCI N-gain; Mean=14.7%.

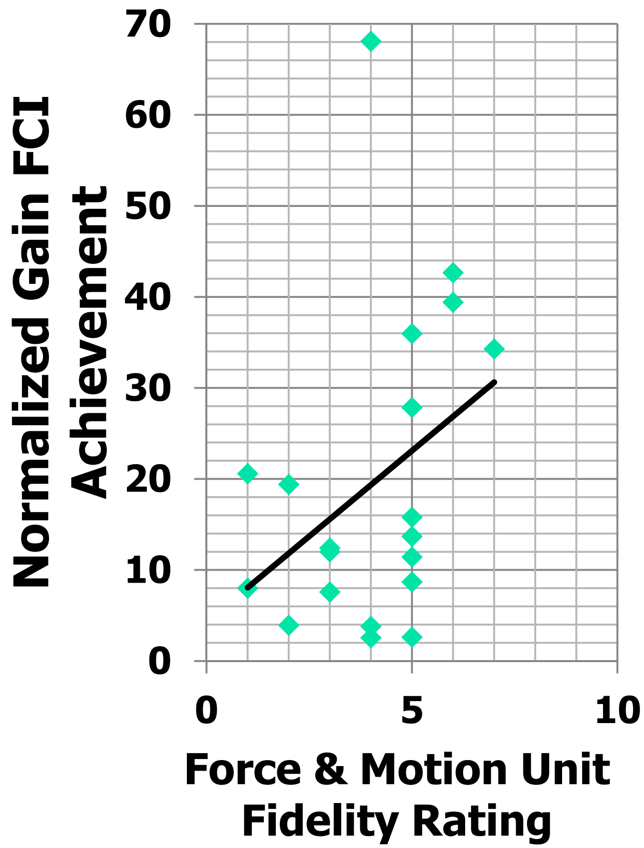


APEX Fidelity vs FCI Summary

3) For sample of APEX Year 2 teachers, **student achievement gains were related to fidelity of use of APEX (PCK) practices**.

Fidelity indicators were rated practices found in Force Motion Unit materials which were compared with students FCI Normalized score gain. Sample FCI N-gain Mean=14.7%

Achievement vs Fidelity of APEX (PCK) Practices



Benchmark Indicators (from teacher classroom action research reports)

Teacher Actions Implemented & Student Achievement

Indicators of APEX performance characteristics with Force and Motion Unit were developed empirically from classroom teacher action research reports.

APEX Fidelity Rating

Involved 18 indicators and a Rubric indicating level of APEX Teacher Characteristics

Rubric	APEX Teacher Characteristics
5. 9-18 Expert use	Demonstrates excellence in implementing and appropriately using MOST of the APEX characteristics, methods, and strategies experienced on the APEX professional development workshops.
4. 7-8 Proficient	Demonstrates evidence of implementing and appropriately using MANY of the APEX characteristics,
3. 5-6 Emergent	Demonstrates evidence of implementing and appropriately using SOME of the APEX characteristics
2. 3-4 Novice use	Demonstrates evidence of implementing and appropriately using a FEW of the APEX characteristics
1. 0-2 Non-use or Trial use	Demonstrates little or no evidence of implementing and appropriately using ANY of the APEX characteristics

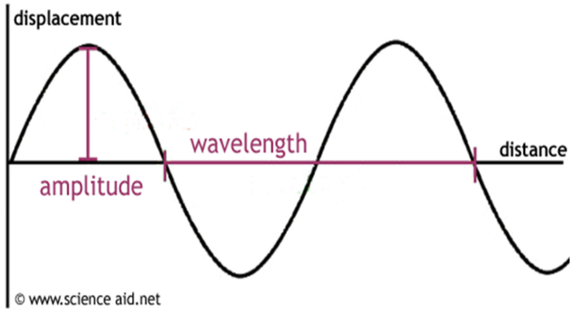
Benchmark Indicators (from teacher classroom Force and Motion action research reports)

Teacher actions implemented related to higher student achievement

Indicators (rated by outside reviewer) of APEX performance characteristics during force and motion Action Research Unit related to **FCI score**

The indicators common to units above the FCI N-Gain mean were

- **Graphical analysis of data** in a 4 step analysis & mathematical modeling
- **Guided inquiry** laboratory activities
- **Identification** and **use of** student **alternative conceptions**
- **Public presentations and argumentation** with students explaining and defending results
- **Use of Technology** to facilitate learning
- **APEX/PTRA and other professional development** lesson materials and teaching used
- **Free body diagrams** used
- **Student talk** and control of learning during lessons



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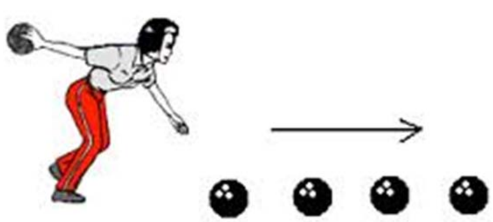
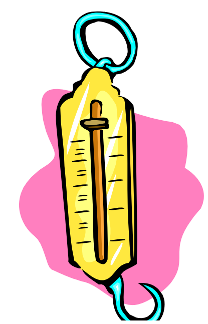


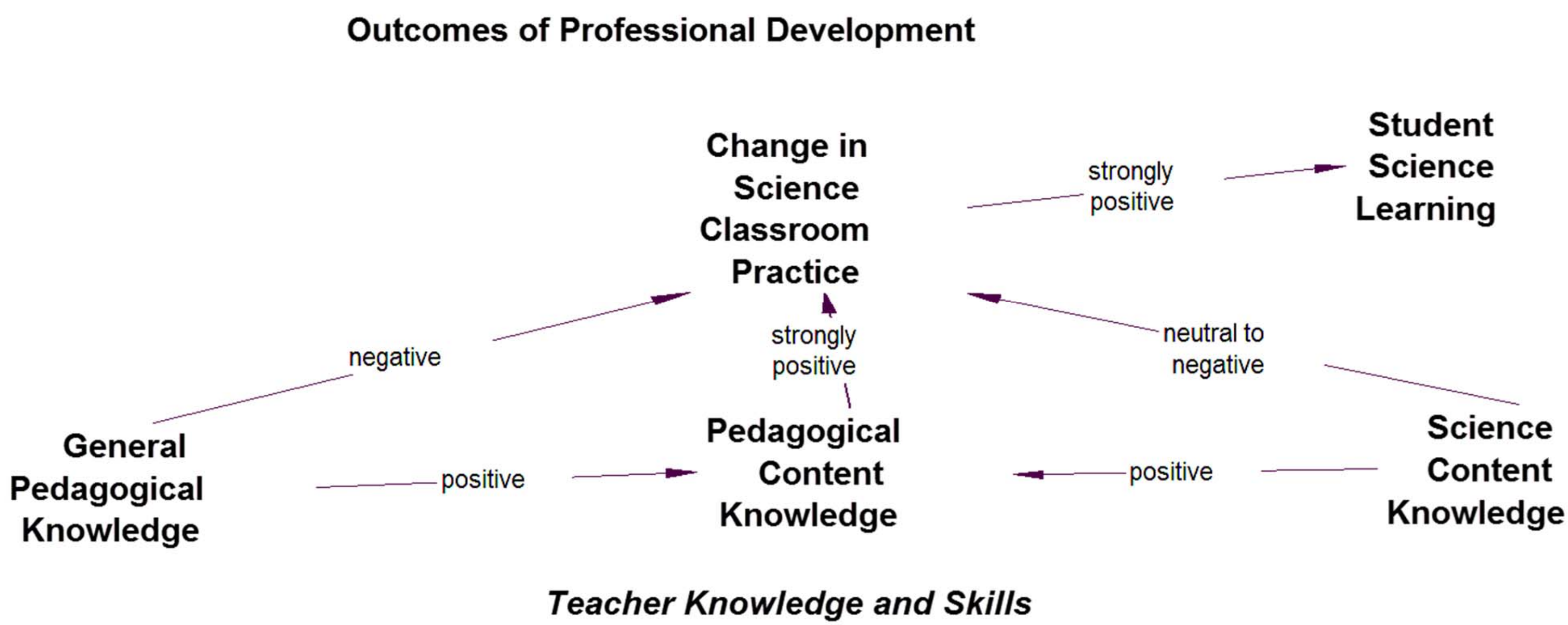


Summary of Findings

- Classroom level of reform practice (performance) increased with APEX PD –
- Teachers knowledge increased with APEX PD – PCK, DCK, PK
- Teacher knowledge and use of student prior knowledge increased with APEX PD
- Student achievement gains were related to RTOP rating of classroom practice.
- Student achievement gains were related to fidelity of use of APEX (PCK) practices
- Teacher use of action research during APEX PD fostered deeper reflection and classroom reform

Implications

Three key components of teacher knowledge <u>were related</u> in effective professional development – pedagogical knowledge, pedagogical content knowledge, and discipline content knowledge



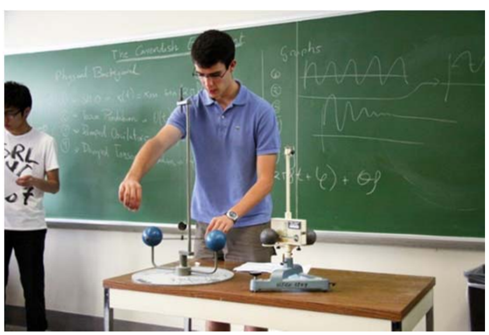
Action Research Facilitates Change in Beliefs

- Over the last two + years we said......

- ***All teachers have beliefs which guide their teaching.***
- ***Beliefs are constructions of reality.***
- ***Can you determine which of your beliefs are "truthful" or "misconceptions"?***
- ***The process of changing is the process of changing beliefs.***
- ***<u>How do you change beliefs?</u>***
- ***<u>How can you change your beliefs about physics teaching?</u>***

Teacher Action Research

Action Research is the only strategy for extending APEX professional development and facilitating and sustaining change this year and in the future.



Professional Development through Teacher Action Research

A data driven evaluation process you must use to monitor your progress in using the APEX information and understandings?

- **Classroom action research adds to your understanding and confidence in teaching and student learning of physics.**
- **Different types of evidence are useful and needed to answer your questions on positive change and physics classroom reform.**

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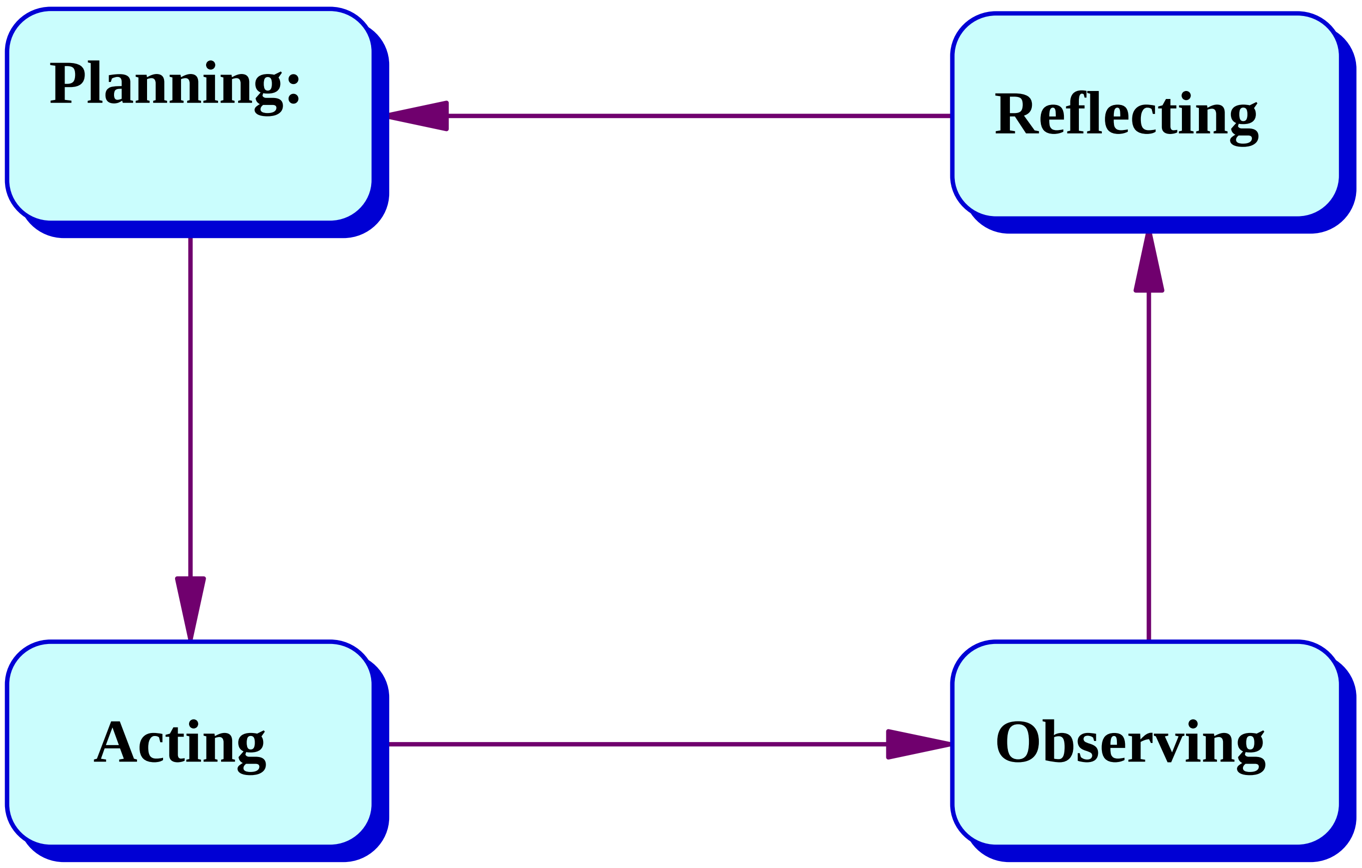
Basic Process of Action Research



Ongoing Action Research Model
(perhaps several cycles for a complex innovation)

A cycle (spiraling) **process:**

- **define problem & determine** (revise) **focus**
- **plan** (modify or use new hypotheses)
- **act, observe & assess** leading to new actions (and new data analysis)
- **reflect, explain & evaluate** (revise previous conclusions)
- **understand through research based practice** (redevelop grounded theory)
- etc.… in a **continuous spiral** leading to self-professional development and change

Take a Break
What do you think?

- **How would you summarize results of change in teaching physics in Alabama?**

Framework for APEX Teaching and Learning (Part of APEX PCK)

I. Know the NGSS and state science learning goals and typical associated learner preconceptions.

II. Engage students in dialogue to allow and encourage them to fully express their initial and developing ideas related to investigating science phenomena, explaining events, and understanding conceptual ideas

III. Conduct inquiry learning activities in which students explore phenomena and ideas and model relationships with the goal of being able to interpret results and explain events.

IV. Engage students in extension/elaboration activities that prompt them to refine their initial thinking and to apply and extend the developed relationships and conceptual ideas in multiple contexts (Learning Cycle sequence).

Framework for APEX continued

V. <u>Monitor student learning and refine instruction through ongoing formative assessment</u> that informs next steps in instruction and provides actionable feedback to students to allow them to evaluate and modify their ideas and practices.

VI. <u>Cultivate a classroom learning culture</u> in which having ideas is valued, where learners share their ideas and use evidence and reasoning in being critical of ideas, while at the same time encouraging, being respectful to and supporting learners sharing their ideas.

VII. <u>Use technology to support development</u> and understanding of physics ideas

VIII. <u>Participate in teaching as a professional inquiry through action research and collaboration</u>.

Discuss Mentoring and Sharing Venues

How can you share and disseminate what you have done in your classroom as reformed or innovative teaching?

1- In your science department?

2- With science teachers in you school system?

3- With science teachers in other school systems?

4- With teachers at science conferences?

5- Other venues?

Inquiry Teacher's Actions and Students' Responses

Essential Features of Classroom Inquiry and Their Variations

Essential Features of Inquiry	1 Full Inquiry Teaching (Can Use Learning Cycle)	2 Coupled Inquiry (Can Use Learning Cycle)	3 Guided Inquiry	4 Directed Inquiry	5 Verification	6 Expository

More <______________________ Amount of Learner Self-Direction ______________________> Less

Less <___________________Amount of Direction from Teacher or Material _______________> More

Essential Features of Inquiry	1 Full Inquiry Teaching (Can Use Learning Cycle)	2 Coupled Inquiry (Can Use Learning Cycle)	3 Guided Inquiry	4 Directed Inquiry	5 Verification	6 Expository
1. Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials, or other source	Learner engages in question provided by teacher, materials, or other source	Learner engages in question that replicates one provided by teacher, materials, or other source	Learner engages in no question to investigate
2. Learner gives priority to evidence in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze	Learner given data and told how to analyze that replicates one provided	Learner given no data just conclusions
3. Learner formulates explanations from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence	Learner provided with evidence that replicates conclusions already given	Learner provided with no evidence, only conclusions
4. Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	Learner provided with connections	Learner provided with connections that replicates one provided	Teacher reports connections
5. Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to sharpen communication	Learner given steps and procedures for communication	Learner reports how close to the textbook the conclusions were	Learner reports no conclusions

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Action Research Related Web Sites

Developing an Action Research Plan with Examples

http://www.bamaed.ua.edu/sciteach

Web-based Action Research Activities:

http://archon.educ.kent.edu/Oasis/Pubs/0200-08.ht

An Introduction to Action Research

http://www.phy.nau.edu/~danmac/actionrsch.html

Action Research-Linked Sites

http://carbon.cudenver.edu/~myder/itc/act_res.html

Virtual Fly Lab:
http://vcourseware3.calstatela.edu/VirtualFlylab/IntroVflyLab.html

Teaching Physics in High School Classrooms: What have we learned II?

Alliance for Physics Excellence (APEX)

Physics Teaching Research Program (PTR)

Dennis Sunal, JW Harrell, Cynthia Sunal, Marsha Simon, Justina Ogodo, Tara Ray, Marilyn Stephens, Michelle Wooten - PTR Team, University of Alabama

APEX PTI Cohort 3 Summer PTI Workshop, June 5-16, 2017