2013-2014 Annual Report

for the

CU Science Education Initiative

Covering periods August 2013-July 2014

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2013-2014 Executive Summary of CU's
Science Education Initiative

The goal of CU's Science Education Initiative (SEI) is to improve undergraduate education in the sciences. For each course, this process involves a three-part process:

1) establishing well-defined learning goals through faculty consensus,
2) creating valid assessment tools for measuring attainment of these learning goals,
3) creating and using pedagogically effective materials and teaching approaches that are:
    - aligned with the learning goals,
    - based on and aligned with established research on how people learn,
    - based on research into student thinking about and learning of the content, and
    - improved through research (assessment and iteration).

Achieving this goal requires substantial changes to the standard university departmental and faculty culture surrounding undergraduate education. The funding provided to departments through the SEI has enabled the hiring of 2 or 3 Science Teaching Fellows (STFs) within each department. The STFs facilitate, guide, and support faculty as they learn about research on learning and engage in transforming their own and the departments approach to teaching. The STFs also investigate student thinking and measure student learning, and by doing so, provide faculty with the data they need to make informed choices about teaching approaches.

After 7 years, a significant number of faculty in 7 departments over the lifetime of the SEI (APS, CHEM, EBIO, GEOL, IPHY, MCDB, PHYS) have been impacted by the SEI, modifying their teaching, creating and using learning goals, and using information on student thinking to guide their teaching. Faculty are engaging in research-based teaching methods and educational issues. The SEI project has also impacted a large number of courses, through in-depth interaction with faculty teaching those courses, developing learning goals in collaboration with faculty, and developing and administering validated assessments of student learning. These changes have impacted over 10,000 students per year, considering courses in which STFs have been both fully and partially involved. The SEI has also impacted departmental culture, affecting the frequency of discussions about teaching and learning in departments, and leading to numerous grants to continue the work begun by the project.

In summary, faculty, current and future students, individual departments, and the university as a whole are substantially benefitting from the investment CU has made in the SEI project. The learning environments and structures are overall more effective; the faculty have defined their learning goals and the curricular materials focuses on achieving those goals; the faculty are better educated in research on teaching and learning, particularly as they apply to the specific content of their courses and how students think about that content; and the faculty engage in and value research on their own student's learning – e.g. through the use of formative assessment tools such as clickers to probe and immediately respond to their students' thinking.

See later reports for more detailed numerical impacts of the SEI.

I. Overview of the Science Education Initiative

The CU Science Education Initiative is designed to implement and coordinate departmental-wide improvement of undergraduate science education. The major goal of the SEI is to bring about the sustainable transformation of the teaching of science on a department-wide basis to employ the research-based methods that have been shown to be highly effective in achieving faculty-defined learning goals.

While it is essential to improve science education at major research universities, the task is formidable. These science departments are large entities with established practices and are subject to a variety of economic and external constraints, providing barriers to change. The approach of the SEI is two-fold: 1) to have the faculty and the department initiate their involvement in and commit to participation in the SEI, and 2) to lower the time and money challenges by providing the funding needed to carry out these department-initiated activities.

The SEI efforts in each department are focusing on sequentially targeting courses for improvement, often beginning with the large introductory courses. Working in conjunction with the participating department, the major elements of the SEI-department efforts for each targeted course include:

1) establishing well defined learning goals,
2) creating valid tools for diagnostic assessment of attainment of learning goals,
3) identifying student thinking,
4) creating and using pedagogically effective materials and teaching approaches, and
5) developing faculty knowledge and practices.

Below, we provide details on the central SEI activities that are being conducted in support of the project. In the last sections, the participating departments summarize the structure of the SEI project within their department, the course-related activities, faculty involvement in the SEI, and departmental goals for 2014-2015.

II. Central SEI Activities

A. Update on central staffing

Dr. Chasteen has served as Associate Director since September 2011, and undertook additional responsibilities related to the SEI such as reporting, STF training, and other duties.

Dr. Kathy Perkins continues to serve as director of the program, and Oliver Nix continues to spend a portion of his time assisting with administrative tasks for the SEI.

B. Funding departmental-based efforts

Several departments have completed their SEI programs. In 2011, CHEM, GEOL, IPHY completed their programs, with PHYS, MCDB, and APS completing their programs in 2014. As of summer 2014, only EBIO has an active SEI program. Two (consecutive, non-concurrent) part-time new hires in EBIO in 2013 and 2013 have allowed for the continuation of activities.

A summary of the activities in each department is provided in the last sections of this report.

C. Activities to support departmental-based efforts

The SEI central staff (Kathy Perkins, Stephanie Chasteen, and Oliver Nix) support the departmental-based efforts in a variety of ways. Programmatic support from SEI Central has been gradually phased out as the SEI reaches maturity and activities are coming to a close.

1. Perkins and Chasteen serve as resources to all of the STFs: advising them on the results of learning research, techniques of education research, and new effective teaching practices; reviewing their activities and progress and providing guidance and advice where needed; and providing them with appropriate professional development opportunities. In addition, they provide central support for certain activities where appropriate (e.g. resource materials for workshops or for administering surveys).
2. To foster communication between departments, Perkins and Chasteen hold occasional meetings with all the STFs – promoting STFs sharing with and getting feedback from the other STFs.
3. Chasteen provides pedagogical support materials (videos, booklets) to STFs for use as they work with faculty on teaching innovations.
4. Chasteen and Nix provide periodic updates to the website on SEI and STF activities.

D. Resources for faculty

The central SEI staff currently provides and is creating additional central resources for faculty working on improving science education on campus.

1. Workshops

Chasteen and Perkins provide periodic workshops through the Faculty Teaching Excellence Program on the use of learning goals and clickers/peer instruction. These workshops are open to all SEI departments, as well as the campus at large. These workshops have impacted over 100 faculty during the course of the SEI project, with potential to impact several thousand students. Materials from past workshops are on our website at http://www.colorado.edu/sei/fac-resources/

2. Teacher guides

In collaboration with the UBC SEI project, we have created a series of teacher guides covering some of the key pedagogical findings from education research and some practical advice on various pedagogically effective teaching practices. Additionally, a detailed resource page on the use of clickers and peer instruction, including videos of use, were developed in previous years. In 2014, a Course Transformation Guide was published on the site, compiling previous white papers from the SEI. These are listed on the SEI website, http://www.colorado.edu/sei/fac-resources/.

3. "Framing" project

In order to support instructors in creating a positive climate for active learning in their classroom, Chasteen has collaborated with researchers at external institutions (Andrew Boudreaux, Western Washington University and Jon Gaffney, Eastern Kentucky University) to identify approaches used by instructors to promote student buy-in of non-traditional instructional techniques. These resources, and preliminary research on instructor use of these materials, are on the SEI website, http://www.colorado.edu/sei/fac-resources/. In 2014, Chasteen received a Chancellor's Award to continue this work.

4. Website

The SEI website provides general information about CU's SEI project and serves as a source for faculty to access information about various education research findings (both general and discipline-specific), handouts and PowerPoint slides from SEI workshops, as well as extensive archives of course materials developed during the SEI. The UBC SEI has a more extensive collection of faculty resources which have been recently mirrored on the SEI website. The website can be found at: http://www.colorado.edu/sei/ and was updated in 2014.

In addition, the CU SEI effort collaborated with the UBC SEI effort to build a much more sophisticated database of resources for faculty that allows faculty to upload their own resources or to search existing resources. This software has been piloted by CU and UBC STF's and faculty, and is available at http://www.sei.ubc.ca/materials/Welcome.do

E. Outcomes and evaluation

As the SEI is in its' final year, Chasteen and Perkins, along with Wieman and Gilbert from the program at UBC, have undertaken to document and analyze the outcomes from the program. This work is ongoing in 2014-2015, but has resulted in the following publications:

Change from Within: The Science Education Initiative
Stephanie Chasteen and Katherine Perkins (CU SEI). Book Chapter, in McDaniel, M., Frey, R., Fitzpatrick, S., & Roediger, H.L. (Eds.), *Integrating Cognitive Science with Innovative Teaching in STEM Disciplines*. [e-reader version] (pp. 298-370

Educational transformation in upper-division physics: The Science Education Initiative model, outcomes, and lessons learned. S. Chasteen, B. Wilcox, M. D. Caballero, K. K. Perkins, S. J. Pollock and C. E. Wieman, Physical Review Special Topics – PER (in review)

A figure representing some of these outcomes is below.

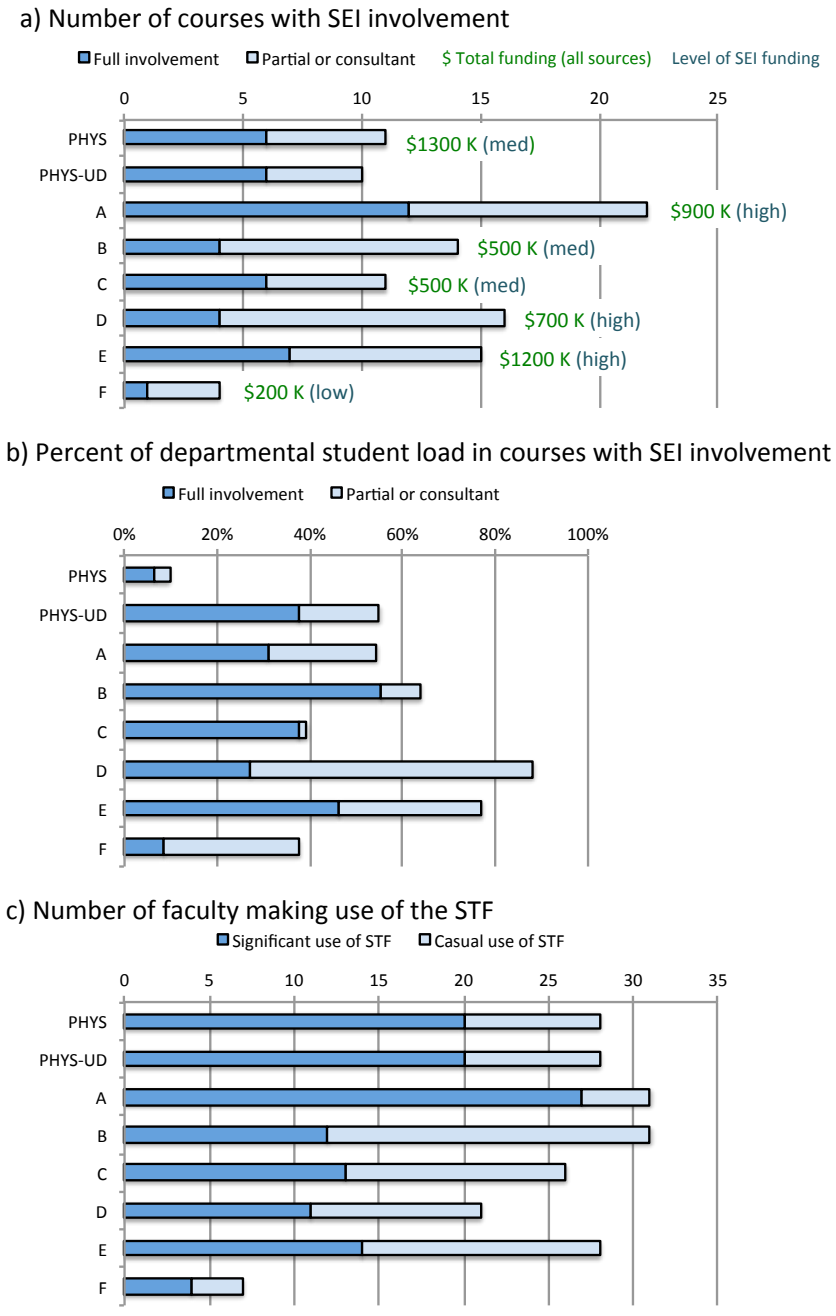

FIG. 1. Impacts of the SEI on courses, faculty, and students.
a) Number of overall courses with SEI involvement. Courses are designated as having full involvement of an STF, or only partial or consulting relationships. Funding is listed from all sources (green), as well as the level of internal funding due to the SEI (blue). For internal SEI funding, "low" is less than 400K, "medium" is 400K-700K, and "high" is 700K-900K. PHYS-UD includes only those courses for majors that are 2000-level and above. "Full" involvement includes focused effort on the part of one or more STF's, often including learning goals, assessment, and instructional materials. "Partial" or "consultant" transformations may include only parts of this approach, or be more casual.

b) Percent of overall student load (across the department as a whole) enrolled in courses with SEI involvement. Student load is defined as the total course enrollment, averaged across AY 2012 and 2013.
c) Number of teaching faculty collaborating with STFs.[1]

Some highlighted results from our analysis of outcomes:

- A total of 46 courses were the subject of focused STF effort; an additional 57 courses were the subject of more casual involvement
- In more successful departments, STFs worked in 30-55% of the courses offered
- The average investment per fully-transformed course was $145,000, considering the cost of STF time
- Learning goals were developed for 65 courses (21% of all courses across departments
- 72 courses made changes related to assessment
- 88 courses made instructional changes
- 135 faculty have modified their teaching in one way (47% of teaching faculty)
- 29 faculty (10%) have developed learning goals, and 99 (34%) have used the SEI's learning goals
- 126 faculty (44%) used information on student thinking to guide their teaching
- 57 faculty (20%) were involved in education research through the SEI
- The degree of success in a department depends on various local factors, such as funding level, departmental culture, degree of faculty rotation, and the characteristics of the departmental chair, SEI departmental director, and STF

[1] "Significant" and "casual" use of the STF was defined individually by the STF and the liaison, but significant use typically included deep involvement on the transformation of a course or a component of a course. Faculty who do not teach undergraduates (including retired faculty) were not included as teaching faculty. PHYS-UD includes only those faculty who have taught upper-division courses since the beginning of the SEI project in 2007.

III. SEI in Astrophysical and Planetary Sciences

The SEI program in Astrophysical and Planetary Sciences began in September 2011.

A. Departmental structure of the SEI program

Two different Science Teaching Fellows were employed during the term of this Initiative. Steve Iona was the STF from fall 2011 through spring 2012. Dr. Wayne Schlingman has been employed from summer 2012 through spring 2014. The work of the STFs was advised by Drs. Seth Hornstein, Doug Duncan and Jack Burns.

The APS department has 4 introductory courses: ASTR1000, ASTR1200, and ASTR1010 and ASTR 1020. ASTR1000 and ASTR1010 teach the solar system, the other two teach stars, galaxies, and cosmology. ASTR1010 and 1020 form a sequence. 1010 has a 2 ½ hour weekly lab, taught by graduate student TAs and several learning assistants (LAs). 1020 was modified to have one hour LA-led recitations after the LA program began approximately 10 years ago. ASTR 1000 and 1200 do not have any small group meetings.

ASTR1010 has had a lab book for decades, with the labs slowly being improved, especially as the department became involved in science teaching research. ASTR1020 had no book of activities for LAs to do in recitation. Historically, each faculty member teaching 1020 simply made up activities for LAs to do. A main goal of the SEI program in APS was to created better materials for the 1020 recitations.

B. Course-related efforts

Recitation Activities for ASTR 1020

Schlingman spent extensive time in the lectures and recitations. He reworked many of the activities developed by the previous STF, Steve Iona, based on student and instructor feedback as well as utilizing the skills and viewpoint of the TAs and LAs working with 1020. Spring 2014 is the 4th semester we have been improving these activities.

The first worksheet we redid and that which had the largest transformation was the "Naked-eye Observing worksheet." It has been streamlined removing wordy descriptions and simplifying it by asking questions that the students investigate rather than being told about. It was broken up into 4 separate worksheets. One that is completed at home that introduces some celestial mechanics. The second walks students through what they will see in the night sky and how to find constellations. The 3rd is a worksheet takes students outside of the recitation under the sky to find all of the objects they found on the computer, and the last is to bring these objects up close by looking at deep sky objects using the Sommers-Bausch telescopes.

The locations of the deep sky objects can also be pointed out in the naked eye observing session and the telescope observing session tying those activities together. Lastly, the telescope observations go beyond what students do in 1000/1010 by using the CCD cameras on the

telescopes to see what these objects look like with different exposure times beyond that of the naked eye. These changes were facilitated over several semesters from student, LA, and TA feedback. We looked at where students were answering worksheets incorrectly or struggled to understand what the worksheet asked. Now the suite of materials is much easier to understand and can be completed faster. Given the new upgrade to Fiske Planetarium this activity is being rewritten further to utilize the upgrades.

During 2013 SEI Fellow Schlingman was employed part-time on an astronomy education research project funded by the National Radio Astronomy Observatory (NRAO) and his STF tenure was extended accordingly. The NRAO funding was used to develop a tutorial about radio astronomy. This is quite valuable as more than half of all astronomical observations nowadays do not use visible light. We developed a tutorial that gets students to explore vibrational and rotational changes in atoms and the photons they emit.

There are 2 solar observing / solar scale activities that have been reworked as well. The observations worksheet has been simplified so students are able to measure sunspots as the move across the face of the Sun to determine the Sun's rotation rate. The second part of this activity still uses the Sun Size lecture tutorial but also adds in a computational part that augments the observations. Students use a fantastic website from the Solar Dynamics Observatory satellite to watch time-lapse videos of the sun taken in different wavelengths. They watch how sunspots move and change over the course of 45 days by looking at the Sun's photosphere. They then explore the magnetic properties of the Sun by using the same date range and look at the UV images that show the magnetic fields above the surface. Students are able to understand the link between magnetic fields and sunspots themselves as well as see that while the sunspots may come and go the magnetic structure still exists. The tutorial compares an image of iron filings scattered on paper above a magnet with the shapes seen near sunspots on the sun. (Both are dipoles!)

The HR diagram activity was revised down in size. In most recitations students only reliably get 30 minutes to work on their activities, which means 5-6 pages are the maximum size students can reasonably be expected to complete. What was left was also reworked to be clearer and simpler for students to follow.

The Stellar Evolution worksheet now combines ranking tasks and a review of the parts of the HR diagram. It walks students explicitly through the stages a low mass star takes as it evolves and ties it directly to what is happening inside of the star. It is set up to help a student organize the concepts into a linear and easy to understand order.

Stellar graveyard is a new activity that was designed by the TA of 1020 in fall 2012. SEI Fellow Schlingman worked with the TA to clean up the text and organize the ideas to help accentuate the differences between a white dwarf, pulsar, and black hole. This activity has undergone significant revisions the past few semesters primarily from LA feedback. There is a quantitative component to this activity and the math has been streamlined to be simpler for students to complete without a calculator. The synchrotron tutorial developed as part of another grant has been added to this activity since compact objects are the primary sources of synchrotron in astronomy.

C. **Other Activities**

In addition to developing and modifying materials, Schlingman has been active in coaching and mentoring LAs to create effective recitation environments. We commonly work on best practices in teaching and practice during weekly meetings. We also meet and talk about what went well and how to improve teaching and implementation of active engagement techniques. The LAs that have come out of 1020 are incredible teachers and are motivated to try new things to help students learn. As part of this coaching we have developed a list of the easiest to implement best practices and common areas teachers go wrong. To help make sure the LAs have a successful teaching experience, Schlingman has supported them in the classroom in whatever way they needed be it materials, knowledge, or classroom management.

In addition to the above worksheets, LAs now each are supposed to rework an activity each semester. The two major revisions they are working on are Standard Candles – Distances in Astronomy and Parallax – based on the activity where we determine the height of the C4C. Schlingman has worked with the LAs to talk about what makes a good activity, their goals for the activity and how to meet those goals. We encourage them to think how they would best learn the material and start from there to build a class worksheet. So far the reworks have been useful given the new format of the LA class. This is a way improvements will continue to be added to 1020 suite after SEI funding is over.
Much of the feedback for improving activities comes from free-response questions, student responses to worksheets, informal student interviews and office hours, as well as a lot of LA and TA feedback when working with the activities. The best feedback we get from the LAs is on the amount of time it takes to complete worksheets, confusion in wording or concept, and redundancies in the activities. All of this is taken into consideration when making changes.

Dissemination to faculty

SEI Fellow Schlingman has spent a lot of time in one on one interaction with the professors teaching ASTR 1020. He sits down and discusses the needs for the class and determine the best activities to use. The past 4 semesters the instructors have been J. Burns, D. Duncan, and W. Schlingman. All have used the activities developed by the APS STFs. Many of the new activities and modifications have been uploaded to the APS teaching wiki as a repository that all instructors have access to.

One of the most important "lessons learned" is that personal interaction with faculty is the most effective way we've seen to spread new teaching activities and techniques. Although a well-organized notebook is important, the extra time Schlingman spent with faculty members, both in their lectures as well as one-on-one was very important.

D. Goals for 2014
Compile the Light and Spectroscopy Concept Inventory results for the past few semesters to show possible differences in learning between the 1200 (non-recitation Stars and Galaxies) to 1020 with recitations.

Continue development of radio astronomy tutorials. Additional field testing and comparison between classes will be done.
The Observing Log needs to be reworked to include a more quantitative comparison of naked eye images to long exposure CCD images.
The naked-eye observing sheet is going to be rewritten to explore using the facilities at the remodeled Fiske Planetarium to explore night sky motions and complete the naked-eye observing challenge. The very realistic Fiske ("Megastar") sky is never cloudy.

E. Publications

The "Radio Astronomy Tutorial" mentioned above will be published in the next edition of "Lecture Tutorials for Astronomy."

The comparison of learning in ASTR1200 which does not have LA-led recitations, and ASTR1020 which covers the same material but with LA-led recitations may be suitable for publication.

IV. SEI in Ecology and Evolutionary Biology

A. Departmental Structure

Andrew Martin (AM) is the faculty supervisor for the EBIO-SEI program. (Note that AM was on sabbatical during the 2013-2014 academic year, although he remained engaged in the SEI activities during the year.) Sarah Wise (SW) has continued as an STF, and Sarah Seiter (SS) was hired as an STF in September 2013.

B. Departmental Support Activities

EBIO 2013 Summer Teaching Retreat

On August 14 and 15, 2013, AM and SW implemented the second annual EBIO SEI Teaching Retreat, themed "Flipping the Classroom" and located in the interactive classroom in MCDB. About 15 EBIO faculty and graduate students were in attendance. The first hour consisted of multiple faculty discussing their successful experiences in implementing active learning. This discussion was summarized and distributed to the entire EBIO faculty. Next, SW presented a model lesson that had been provided in advance by Sam Flaxman and "flipped" by SW to involve pre-reading, a quiz, and an in-class activity. This was followed by a general discussion of the lesson and the larger "toolbox" of flipping instructional opportunities. The second day, small groups chose a lesson from among their courses to flip using a limited number of techniques, and presented that lesson to the larger group just before lunch. The lessons that groups developed included clicker questions, card sorting, and in-class problem solving. The flipped sample lessons were archived and shared with the larger EBIO faculty. The retreat concluded with a potluck party at Andy's house. The third annual retreat is planned for August 2014, featuring the themes of "Active Learning Technology" and "Data Driven Reflection".

EBIO Departmental Learning Goals

In September 2013, the EBIO Curriculum Committee (CC) decided to make Departmental Learning Goals a focal project. SW consulted during a CC meeting during which it was decided to endorse the project to the whole EBIO faculty. SW led an EBIO faculty meeting on November 7 to discuss the goals, outcome and process. At the conclusion of the meeting, the faculty voted to pursue a process of gathering data on existing overarching course learning goals, followed by consolidation of such goals and wordsmithing. In January 2014, 21 EBIO faculty completed a survey prepared by SS and SW, where they described the overarching learning goals for each of their courses. These data were compiled by SS and discussed during an EBIO faculty meeting on January 23, which SS and SW facilitated. The outcome of that meeting was to pursue the creation of two documents, one to describe goals for all EBIO majors, and a second to describe goals which EBIO majors could opt to pursue depending on their path through the major.

SS and SW then split the submitted goals, along with goals drawn from published sources and other universities, into 11 process and content categories and polled EBIO faculty for their preferences on working on one or more of these categories. Using the poll data, SW assigned every EBIO faculty member to a working group and SS and SW developed guidelines for working groups to follow. To date, working groups have submitted a total of 13 draft goals covering 5 categories. Additional working group meetings will occur over the summer and we expect the EBIO faculty to discuss draft goal documents during early fall 2014.

Development of an EBIO Major's Assessment.

APM, SW, SS and John Basey continued work developing a process skills-oriented assessment tool that can be used to measure learning gains for EBIO majors. SW coordinated a student to transcribe video interviews from the spring 2013 pilot study of 7 questions. That information informed the revision of the assessment. A second pilot was conducted in spring 2014 using a 13-question instrument. It was administered in 4 EBIO upper division classes and one EBIO introductory class, to a total of 94 volunteer EBIO majors and minors, and 68 students affiliated with other departments. Analysis is ongoing. Future versions of this assessment will be aligned with EBIO Major's learning goals, once the learning goal development process is completed.

SITAR Observational Tool

Development of the SITAR teaching observational tool began in fall 2011 by AM, SW, and former STF Anne-Marie Hoskinson, in collaboration with EBIO faculty. SITAR is "descended with modification" from RTOP, TDOP, a pilot version of COPUS, and the Student Engagement Protocol (unpublished, Erin Lane, UBC CWSEI).

When SS joined the EBIO-SEI team, she redesigned its "dashboard" of automatic visualizations and expanded those visualizations to include longitudinal trends, which greatly increased the usefulness of the SITAR for faculty reflection. There are four quantitative observational modules of the SITAR, to which qualitative notes can be appended. They are: a customizable *Teaching Activities* module, which in 2013 we began to customize based on the interests of individual faculty; a *Student Engagement* module*;* and a unique *Student Interactivity Sample* module. The final version of SITAR will be archived to the SEI website this summer.

During academic year 2013-14, the SITAR was used to support the observation and reflection of 8 EBIO faculty and 2 postdoctoral fellows: Sam Flaxman, Dan Medeiros, Erin

Tripp, Nolan Kane, Becca Safran, Piet Johnson, Kendi Davies, Brett Melbourne, Julian Relasco, and Leigh Cooper. Ten graduate students in Nichole Barger's *Science Education Seminar* were also trained in using SITAR to take observations and interpreting SITAR data. During the spring semester, SW coordinated a successful pilot project in which senior undergraduates collected SITAR data. This summer, analysis of SITAR data is being used to prepare detailed letters of support for these faculty's files, including two who are up for tenure review.

This year's SITAR development work led naturally to an NSF proposal to the PRIME program entitled "Research and Development of the COCTAIL App: A Revolutionary Tool for Formative Assessment of STEM Instruction". The proposed app would provide a common, customizable platform for all published college-level teaching observation instruments, as well as the *Student Interactivity* and *Teaching Activities* modules of the SITAR.

C. Course and Faculty Support Activities

a. Activities led by Andrew Martin; May 2013 – May 2014

Curriculum development

All active learning, student-centered curricula developed for EBIO 3080 (Evolutionary Biology) were written in a manner that permits distribution to the community of educators in evolutionary biology. Many of the lessons were adopted by instructors at other colleges and Universities by requests to APM and through the Martin lab website where a number of lessons are published and can be readily downloaded (http://spot.colorado.edu/~am/Site/Teaching.html).

Faculty observation and mentoring

AM observed multiple courses for two faculty (Nolan Kane and Daniel Medeiros) and provided feedback and mentoring based on quantitative and qualitative data stemming from the use of SITAR.

b. Activities led by Sarah Wise; May 2013-May 2014

General Biology I and II

During the summer of 2013, SW coordinated the work of course coordinator Derek Sweeney (DS) to reform the homework of 2 General Biology II faculty, Becca Safran (BS) and Piet Johnson (PJ). Existing homework assignments were modified such that there was a section of questions reviewing the previous week's material, followed by a section of questions on the reading for the upcoming week.

During fall 2013 and spring 2014, SW assisted 5 General Biology faculty (Dan Medeiros (DM), Kendi Davies (KD), Brett Melbourne (BM), BS, and PJ) primarily with weekly class observations and feedback, along with limited and targeted curriculum development. SW coordinated the work of 2 undergraduate students to collect SITAR data for PJ, KD, and BM. SW also consulted frequently with course coordinator DS, particularly around his guidance of TAs and undergraduate TAs in the classroom.

During summer 2014, SW wrote letters for the files of these 5 faculty, and is coordinating the work of a student to analyze pre-post assessments for these 5 faculty, and compile notes, clicker data, Bloom data and student attitudes survey results for KD and BM.

Transformation of the General Biology course sequence is nearly complete, and clicker questions and learning goals have been archived at the SEI website. The only additional planned curricular work in 2014-2015 is to better integrate "history of life" and "march of the phyla" lectures for Becca Safran and Piet Johnson, and assist Dan Medeiros as needed in flipping the sequence of genetics topics (to molecular first, followed by Mendelian).

Faculty Consulting

In fall 2013, SW consulted with new EBIO faculty member Erin Tripp on the design and implementation of her undergraduate Plant Systematics course and a student mid-semester survey for that course. SW provided advance comments on two of Erin's lectures, observed those sessions, and provided Erin with feedback including SITAR data. SW used these observations to characterize Erin's teaching in a letter for her file. Following this experience, Erin indicated an interest in making this class increasingly active during lecture, over time.

In fall 2013, SW consulted with Sam Flaxman (SF) on the design and implementation of a new graduate course (TheorEE: Building Models in Ecology and Evolution) structured around a "flipped classroom" model. SW helped SF survey graduate student interest around topics and course components, and develop his learning goals for the course. SW observed and provided SITAR data and feedback about Sam's teaching in this class several times over the semester. Through this experience, Sam clearly applied teaching techniques that he had developed in his General Biology teaching and extended them to become a skillful manager of a heterogeneous group of students working primarily in small groups during class time.

Over this same time span, SW carried out a similar (though less intensive) consultation with Kendi Davies (KD) on the design of a "flipped" graduate seminar (Community Ecology) based on the CREATE model of engaging students with primary literature. In the course of two meetings, SW and KD worked to refine KD's learning goals, developed a weekly structure for the course, and discussed how to structure and implement student assignments and rubrics. KD did not feel that observations or feedback were necessary for this course. Kendi's description of her teaching experience in this class was "magical".

In late fall 2013, SW presented a "getting started with Clickers" workshop for 2 new EBIO faculty (Christy McCain and Nolan Kane), and 2 postdoctoral instructors; assisted by SS.

In spring 2014, SW assisted Pam Diggle and her TA with review and advice on a group presentation rubric. SW and Sarah Seiter also consulted with Stacey Smith on the design of a course proposal to expand the credit hours and lab components of "Plants and Society", and to add a significant writing component. SW developed a sample writing assignment to be included in the proposal. SS and SW will help Stacey Smith coordinate graduate student support for curriculum development through Nichole Barger's graduate seminar on teaching and learning during fall 2014.

During summer 2014, SW is consulting with Carol Wessman around structuring student discussion within an existing lecture-based class, "Landscape Ecology". SW will review reorganized lecture materials over the summer and either SW or SS will carry out observations with feedback during fall 2014.

c. Activities led by Sarah Seiter; August 2013- May 2014

Faculty Consulting:

SS consulted with Stacey Smith, providing feedback on her materials for use as a guest lecturer in the *Evolution* course (described in greater detail below). SS also consulted with Stacey on the development of her *Plants and Society* course, assisting on a proposal to expand it from 3 credit hours to 4. SS also suggested using popular science writing and journalism as a focus, and provided a list of local science journalists and communicators to invite to the course. SS also met with Leigh Cooper, to offer suggestions for utilizing clicker questions in her *Limnology* course. She also helped Leigh Cooper to locate case studies for use in the course through the National Case Study Library.

Evolution:

SS and Nolan Kane co-taught a flipped classroom evolution course during Spring 2014. Beginning fall 2013, we developed a set of learning goals and outcomes for the course, and solicited feedback on them from other faculty. We then developed a syllabus and the first six weeks of course materials for the coming semester during this time, including laboratory activities, clicker questions, assessments and class activities. We also conducted a two-stage hiring process to select six learning assistants (LAs) for the coming semester.

During Spring semester we implemented the first six weeks and developed the remaining curriculum materials for the course. In total, we developed 45 active learning lectures with clicker questions or written exercises to accompany them, as well as 30 homework assignments. These will be archived on the SEI website.

In addition to teaching the course, we mentored the TAs and LAs in producing active learning case studies (the LA team and TA team took two lessons each to implement their case studies). SS and Nolan Kane provided feedback before and after the case studies were implemented, and SS and the LA team are preparing the case studies for publication in the National Case Study Library at SUNY Buffalo. SS and Nolan Kane also developed a "crowd-sourced" class experiment, testing the effect of road salt, shade and drought on sunflower seedlings. Students designed experiments and voted on the experimental design in class. They then implemented their experiment and presented their data using posters (see below, "Scientific Posters as an Authentic Assessment Tool").

Nolan Kane, the LAs, TAs and guest faculty received feedback regularly from SS. SS led weekly meetings with the LAs, TAs and Nolan, and reviewed Nolan's materials on a weekly basis and provided feedback on his teaching after every class. In addition to informal feedback, a member of the undergraduate research staff collected quantitative data on Nolan's teaching performance using the SITAR, and SS and the undergraduate reviewed this data with Nolan after each class. SITAR data indicated that student centered behavior and student engagement increased over the course of the semester. SITAR data on the LAs and TAs indicated that their student centered behavior and student engagement were well within the range of the primary instructors. Stacey Smith guest lectured for two classes, and received feedback on her materials and was provided with SITAR data as feedback on her teaching.

EBIO Science Education Seminar

SS collaborated with Nichole Barger on a graduate student seminar both semesters. During fall semester, the students in the seminar wrote a paper on developing new models for pedagogical training in graduate schools. The manuscript, now in review at the *Journal of College Science Teaching*, details a model in which graduate students gain progressively more responsibility and create curriculum and practice classroom management skills through faculty teaching partnerships. During the second semester, we implemented part of the plan outlined in the manuscript, by offering a seminar in curriculum development for graduate students. The seminar covered basic pedagogical theory during the first few weeks, and then students developed and tested case studies for use in classes that they were teaching or TA-ing. Several of the case studies were submitted for publication at the National Case Study Teaching library. Nichole Barger and SS submitted a proposal to expand the seminar into a formal training program, in line with the reforms proposed in the manuscript(described in the next section).

D. Research and Scholarly Activities

EBIO Graduate Educational Training Program.

Nichole Barger and SS received a Chancellor's iStem grant for $9,707 to expand the graduate *Science Education Seminar* into a multi-year training program (proposal title: "Transforming Graduate Training in STEM Education"). In our expanded program, students will participate in a four day summer workshop on curriculum development, where they will be matched with faculty partners. Faculty and graduate student teams will develop active learning units for implementation in courses. During the fall semester, students will provide feedback and revision on each other's curricula and begin testing their materials in the classrooms of their faculty partners. Students will receive feedback from their faculty mentor, from the instructor, and from their peers before, during, and after implementation of their materials.

Group Sign-Up Experiment.

This project began in spring 2012 as a collaboration between Kendi Davies, Brett Melbourne, and Sarah Wise. In fall 2013, Sarah Seiter took over the analysis of student attitude survey, clicker survey, CQ performance, post-test performance, and exam performance data from this study. SS has been creating composite variables for student clicker performance and group characteristics, and is using generalized linear mixed effects models to measure the effect of group composition and stability on clicker performance.

NSF TUES Clicker Discussion Experiment.

Sarah Wise, Jenny Knight, and Erin Furtak were awarded $150,000 in June 2012 to carry out "Investigating Instructional Influences on Clicker Discussions". During Fall 2013, Sarah worked with undergraduate research assistants Sarah Zimmerman (SZ) and postdoctoral fellow Jeremy Rentsch to collect data in the General Biology I class. Sarah also collaborated with Sam Flaxman during this time on the design and implementation of the experimental treatment, which involved randomly calling for student ideas following clicker discussion. During this semester, Jenny Knight coordinated studies in MCDB classes in which Learning Assistant (LA) interaction and random call of groups were the experimental treatments.

Data analysis of both 2012 and 2013 TUES data is ongoing. Interrater reliability has been achieved for the coding scheme that the researchers developed. Data indicate that the 2012 "cues

and modeling" treatment positively affected student attitudes toward group work and discussion, and stimulated students to engage in more questioning and exchange high quality reasoning more frequently. The 2012 "LA interation" study results indicate that LAs benefit student discussion primarily through their use of questions, and may have a detrimental effect when they provide explanations. Papers on the 2012 studies are being prepared for submission this summer.

Metacognitive Exam Review Study. In May 2013, SW was awarded a $10,000 Chancellor's Award for STEM Excellence proposal with co-authors Barbara Demmig-Adams and William Adams. Entitled "Assessing the Impact of Early, Individualized Faculty and TA Interventions for At-Risk Students." Over the summer of 2013, this project was expanded to include the MCDB 3135 class. Quite a number of alterations to the design of the study took place prior to the implementation of the instructional intervention, which was a metacognitively-oriented exam review. A graduate student teaching a co-seminar of McNeill program students performed the EBIO intervention and Joy Power, the lab coordinator for MCDB 3135, performed the MCDB intervention. An online intervention tool was also piloted in MCDB 3135, during the second half of the semester. Nonparametric tests indicate that neither the face-to-face nor online exam reviews impacted student performance on subsequent exams, compared to students that did not engage in such reviews. Regression analysis to explore possible interactions between the exam review impact and individual student characteristics is ongoing.

Poster sessions as authentic assessments.

J. Harrison Carpenter, Nichole Barger, Nolan Kane, Miranda Redmond and SS collaborated to implement a joint poster session as a capstone project for the upper division courses, held in the University Memorial Center. Over 200 students collaborated on the posters and presented in the session. Nolan Kane and SS used argumentation and verbal presentation as a major assessment for the students in the Evolution course and developed a rubric to measure performance on poster presentation.

Professional meetings

AM presented a poster at an international meeting (Evolution) in summer 2013 that documented course transformation and the use of student-directed research and a poster session. AM and SS will also be presenting another poster on the same topic (different specific content) at this year's Evolution meeting. SW is presenting a talk and two posters (with Jenny Knight, Jeremy Rentsch and a student) on her NSF TUES research work at this year's SABER meeting.

V. SEI in MCDB

A. Departmental structure of the SEI program

Previous STFs	Current Position
Dr. Sarah Wise	STF in Ecology & Evolutionary Biology (EBio)
Dr. Jia Shi	Instructor, Integrative Physiology (IPhy)
Dr. Michelle Smith	Assistant Professor (UMaine)
Dr. Brian Couch	STF (Jan 2012-July 2014); current position, Assistant

Professor, University of Nebraska, Lincoln

B. Course-related efforts

No courses have been the target of STF work in the past year. Brian was hired to develop the Capstone Molecular Biology Assessment, which we hope the department will implement for graduating seniors as a measure of learning over the course of the major.

C. Development of a Capstone Assessment tool for MCDB majors

(from last year's report):

Previous discussions with MCDB faculty and the departmental Undergraduate Committee (UGCOM) led to an agreement that the best way to sustain and improve research-based teaching in our core courses would be to develop an assessment tool to monitor if our students are graduating with the knowledge and skills that the department values as essential. Administered each year to seniors and intended to measure students' ability to integrate and apply their knowledge, this "capstone" assessment would direct the attention of the faculty toward specific areas of difficulty and help shape our curriculum and teaching. Coupled with instituting a process for periodic review and updating of core course learning goals, this should ensure that core courses are adequately addressing the overall learning goals of the program.

The assessment is aimed at probing higher-level cognitive understanding of central concepts in biology, and consists of 18 multiple true/false questions. The assessment was designed through the following steps:

Step 1: Identify major concepts in biology and draft a set of related learning goals. Our learning goals are the product of roughly 20 faculty interviews, extensive textbook review, and student group discussions. Our final learning goals are framed within the core competencies recommended by the Vision & Change in Biology national report.

Step 2: Collect student thinking related to learning goals. For each concept, we drafted an open-ended question to probe student thinking and conducted interviews with 7-12 students per question.

Step 3: Draft forced-response questions based on student thinking. We elected to use the multiple T/F question format because it provides a much richer portrait of student thinking than simple multiple choice. We proceeded with validation efforts for 18 of these questions.

Step 4: Iteratively revise questions based on student and faculty interviews. For each question, we have conducted think-aloud interviews with 6-19 students and collected feedback from 7 faculty. We are presently working to conduct more student and faculty interviews and to bring questions into their final versions.

Step 5: Determine validity of final version through student interviews and faculty feedback. Once we have arrived at the final versions of each question, we will conduct a final set of student interviews to measure how well our items capture student reasoning.

We will also send a survey to diverse faculty asking them to evaluate the content and appropriateness of each item.

Step 6: Administer pilot test to a large number of students and perform statistical analyses to determine evidence of validity and reliability.

Work completed this year:

Measuring students' conceptual understandings has become increasingly important to biology faculty involved in evaluating and improving departmental programs. We developed the Molecular Biology Capstone Assessment (MBCA) to gauge comprehension of fundamental concepts in molecular and cell biology and the ability to apply these concepts in novel scenarios. Targeted at graduating students, the MBCA consists of 18 multiple true-false (T/F) questions. Each question consists of a narrative stem followed by four T/F statements, which allows a more detailed assessment of student understanding than the traditional multiple-choice format. Questions were iteratively developed with extensive faculty and student feedback, including construct validation through faculty reviews and response validation through student interviews. The final assessment was taken online by 504 students in upper-division classes at seven institutions. Data from this administration indicate that the MBCA has acceptable levels of internal reliability ($\alpha = 0.80$) and test-retest stability ($r = 0.93$). Students achieved a wide range of scores with a 67% overall average. Performance results suggest that students have an incomplete understanding of many molecular biology concepts and continue to hold incorrect conceptions previously documented among introductory-level students. By pinpointing areas of conceptual difficulty, the MBCA can provide faculty with guidance for improving undergraduate biology programs.

The MBCA development paper has been accepted for publication in CBE-Life Sciences Education (see reference below).

Another paper on the development of a taxonomy of Scientific Teaching Practices has also been accepted for publication in CBE-Life Sciences Education (see reference below).

D. Faculty Presentations/Synergistic activities. Fall 2012/Spring 2013

Jenny taught MCDB 5650-Teaching & Learning Seminar in spring 2014. There were 15 participants in the class, including undergraduates, graduate students, and postdocs from several different departments.

Jenny, Brian and Bill attended the SABER conference in July. Jenny and Brian gave posters. Jenny is the head of the abstract review committee for SABER.

Jenny and Bill led the National Academies and HHMI Mountain West Summer Institute on Undergraduate Biology Education at CU-Boulder in late July.

Jenny gave invited talks at several different universities around the country.

Brian moved to University of Nebraska-Lincoln in July, 2014.

E. External funding:

No new external funding was obtained this year.

F. Publications of SEI-related research by SEI team members, 2013-2014

Couch BA, Brown, TL, Shelpat, TJ, Graham, MJ, **Knight JK**. *in press.* Scientific Teaching: Defining a Taxonomy of Observable Practices. *CBE Life Sci Educ.*

Couch BA, Wood WB, **Knight JK**. *in press.* The Molecular Biology Capstone Assessment: A Concept Assessment for Upper-Division Molecular Biology Students. *CBE Life Sci Educ.*