Extended Abstract

The CREATE method (Consider, Read, Elucidate the hypotheses, Analyze and interpret the data, and Think of the next Experiment) is an approach to teaching science content and analytical reading skills and to impact student perceptions of science and scientists using primary literature (www.teachcreate.org). The CREATE method, uses scientific papers as an avenue to investigate both science content and the process of science itself. In this study, a modified CREATE approach was used to integrate reading and analyzing journal articles into BIO182, an introductory biology course for science majors. In addition to the regular course curriculum, four primary research papers were read and analyzed. The papers were selected based on relevance to concepts covered in the course, recent publication date, and general interest to the students. Individual and group activities were used to integrate the learning into the course, some activities were graded and some were not. Activities included concept mapping, cartooning of experimental design, paragraph summarizing, group presentations, data transformation, and figure annotation.

An anonymous Pre/Post survey instrument was used to measure the impact of the CREATE process on four areas of student learning: Understanding, Skills, Attitudes, and Integration of Learning. The survey comprised Likert Scale questions that covered topics ranging from students' attitudes towards research careers, ability to identify patterns in data, confidence in decoding scientific jargon, ability to recognize a sound argument and identify appropriate evidence, and understanding how to concept map.

The surveys showed that students in classes exposed to the CREATE process made significant gains in all four areas compared to their peers in a similar but unmodified BIO182 course. The largest gains were seen in the area of skill and comfort with reading scientific journal articles, which may not be surprising since for many of these students these were the first research papers they had ever read. However, significant gains were also seen in the areas of understanding and attitudes, and to a lesser extent, integration of learning. Understanding and attitudes measured students' understanding of how to approach a research paper and and their confidence in their abilities and enthusiasm. Integration of learning measured the students' comfort with applying their skills to other areas of their life and studies and also with various aspects of metacognitive development.

This study clearly demonstrates that integrating a modified CREATE approach into an early majors-level course can positively impact student learning in many areas. The positive gains in attitudes and confidence are important in view of the high levels of attrition seen in the early years of STEM curriculum. In addition, the CREATE methodology may be particularly valuable in a community college setting to prepare students for the rigors of reading in upper division courses they will encounter post-transfer at a four-year institution.

Introduction

Interest in science often wanes in the Middle School years and much of this has been attributed to a lack of applied content in the curriculum, which often continues through High School and beyond. In recent years, a greater and greater emphasis has been placed on contextualizing science education by teaching content using applied examples (Ambrose et al. 2010) and incorporating various active learning pedagogies while doing so (Coil et al. 2010). Pedagogical examples of active learning techniques include Problem-Based and Case-Based learning, Inquiry-based learning and Modelling and significant effort and funding has been directed towards educators at all levels to promote these practices within science education across the United States and beyond (NRC BIO2010 Report).

Furthermore, there has been a push towards teaching the process of science alongside the facts of science. Science educators across the board are being encouraged to promote STEM research careers to students (AAAS 2011, www.visionandchange.org/finalreport). Many textbooks have added side-bars and case studies highlighting a particular research study with relevance to the chapter in question and have also included "researcher interviews" to introduce students to the people behind the ideas and information. Research has shown that most students, even science majors in college, still do not have a strong understanding of the process of science in general, and many do not seem to feel any connection to the lives of scientists themselves.

In teaching biology, many faculty suffer from what is known as the "tyranny of content" – the endless and ever-expanding amount of "Stuff We Know About" and therefore feel duty-bound to tell students about. However, it has been documented that students may be poorly prepared for college-level science, feel overwhelmed by the amount of new information covered in the introductory-level courses (Seymour and Hewitt, 1997), or be discouraged by textbooks' depiction of biology as a largely descriptive science (Duncan et al., 2011).

The CREATE method offers one way to avoid the didactic delivery of reams of content, yet still cover adequate content in a highly contextualized and applied manner that provides a rich and engaging student learning experience. The method was devised to Sally Hoskins to address the various issues described above. CREATE (Consider, Read, Elucidate the hypotheses, Analyze

and interpret the data, and Think of the next Experiment) is a teaching approach that uses intensive analysis of primary literature to demystify and humanize science for undergraduates. “Journal articles – the real currency of science — are used as an inroad to understanding “who does science, how, and why?” “ (www.teachcreate.org) . In summary, students read and analyze sets of carefully chosen papers using various approaches (concept mapping, cartooning, visualization and transformation of data) to gain a progressively deeper understanding of the science behind each paper. In a stepwise manner students learn to interpret complex data, draw conclusions, debate interpretations and suggest/evaluate the next experiment. Content knowledge is reviewed as students encounter the background behind each paper. Late in the process students generate a short list of questions for the papers’ authors to gain an insight into the people behind the research. The CREATE method was originally used as the basis for a Junior/Senior level biology majors course (Hoskins, 2011), but has since been modified for use in a freshman level course (Gottesman and Hoskins, 2012). When using the CREATE approach, significant gains were seen in students’ critical thinking, experimental design abilities and their perceptions and understanding of science improved (Hoskins, 2011; Gottesman and Hoskins, 2012).

In this study I used a modified CREATE approach to augment an existing community college biology curriculum. The goal of adding the CREATE-based modules to the course was not to teach biology content per se, but to increase students’ ability to critically read and level of comfort with reading primary research papers and to increase their understanding of the process of science and of the lives of scientists who engage in the process every day. The CREATE-based modules were developed and used in BIO182, the ecology/evolution/diversity/physiology portion of a two-semester Majors Introductory Biology sequence, taught at a community college in Arizona. Students enrolled in BIO182 have already passed BIO181 (cellular/molecular biology) and are generally on a four year STEM bachelor degree track. There were several reasons why this course was chosen for the study. Firstly, integrating primary literature into the BIO182 curriculum will expose more prospective science students to the scientific process at an early stage in their academic careers and help them see what biologists actually “do”. Many students assume a science degree is a path to either become an engineer or a doctor and they have no idea about the other careers open to them in research. Secondly, by its very nature the CREATE method relies heavily on critical reading of scientific literature. This is a skill that can only be developed by lots of exposure to the material

and guided practice. In general, community college science students do not read primary science literature and have little to no experience in analyzing and critiquing experimental design, results or conclusions. The implementation of CREATE-based modules in this Sophomore level class may be expected to positively impact students' ability to read and understand peer reviewed scientific journal articles and to increase their comfort level with reading, understanding and analyzing technical material, which is a skill that will be of great value in their upper division classes post-transfer. Transfer shock is a well documented phenomenon (REF) and while much research has been done on interventions at the university to mitigate transfer shock little has focused on curricular modifications that could occur at the community college to better prepare students for upper division courses.

Methods

Two cohorts of students enrolled in BIO182 (Introductory Biology for Majors II) at Estrella Mountain Community College during the 2015/16 academic year received the pedagogical intervention. In addition to the regular course content, Cohort 1 (Fall 2015) read and analysed two papers from the primary literature, one during Unit 1 and one during Unit 4. Cohort 2 (Spring 2016) read and analyzed four papers from the primary literature, one in each of the four course units. The papers used are detailed in Appendix A. The control cohort comprised a third BIO182 class, taught by a different instructor, but using the same class materials and same LMS Course shell, without the additional primary literature activities and assignments.

A wide range of instructional approaches was taken when introducing students to the papers. Most of these were taken from the original CREATE method, including creating concept maps, guided reading, cartooning of the methods/experimental design, summarizing paragraph by paragraph, and annotating figures. Some of these activities were assigned individually, some were done in groups, some were graded and some were not. As previously described, Cohort1 did this for two papers over the course of the semester, and Cohort2 did this for four papers over the course of the semester.

All three cohorts completed the same pre- and post-test to measure various aspects of their self-rated ability and confidence in reading scientific literature and their attitudes towards science, the process of science and scientists. The test instrument (Appendix B) had been previously developed by Justin Anderson (Radford University) for use in a CREATE based

Biology class in 2013. The pre-tests were taken during the first weeks of the semester, prior to any of the supplemental activities. The post-tests were taken in the last week of the semester, after all supplemental activities had been completed by the experimental cohorts. Surveys included statements that were phrased negatively and positively and students answered on a Likert type scale that provided options of: a great deal / a lot / somewhat / just a little / not at all / not applicable. The survey focused on four areas: 1. Understanding; 2. Skills; 3. Attitudes; 4. Integration of Learning and there were between four and nine questions in each area. There were also several open ended questions on the survey. Surveys were conducted anonymously using www.salgsite.org. The SALG (student Assessment of Learning Goals) website is a free course-evaluation tool that allows college-level instructors to gather learning-focused feedback from students. Survey Data was downloaded in MSExcel and analyzed using the statistical analysis software R.

Results

Figure 1 summarizes the average scores from the Likert Scale responses on the pre and post surveys for both experimental cohorts (Cohort1 = Fall15, n=22; Cohort2 = Spring 16, n=21) and the control cohort (n=8). The survey responses were scored between 0 and 6 where 0 corresponded to not applicable, 1 to the least desirable answer and 6 the most desirable answer. A shift towards a higher score would indicate that students were self-reporting a higher level of comfort, skill or understanding in their responses to the questions. It is clear that for both the experimental cohorts, an increase in their average responses occurred. For both experimental cohorts the overall increase was highly significant (detailed in Table 1), while no significant difference was seen in the overall pre and post survey responses of the control cohort.

Additional analysis looked at the separate sections of the survey that aimed to measure Understanding, Skills, Attitudes, and Integration of Learning. Table 1 details the differences in the pre and post test scores from the experimental cohorts and the control group for each section of the survey. Increases were seen for all areas for both cohorts. All increases were statiscially significant except for Attitudes for Cohort1 and Integration of Learning for Cohort 2, but in both these cases the increases were close to significant ($p=0.06$). In contrast, the control cohort only showed a statistically significant increase in the area of “Skills” and the increase was

0.21, compared to statistically significant increases of 1.1 and 0.71 in the same area for the experimental groups. The control group also showed a statistically significant decrease in responses in the Integration of Learning section.

Figure 1

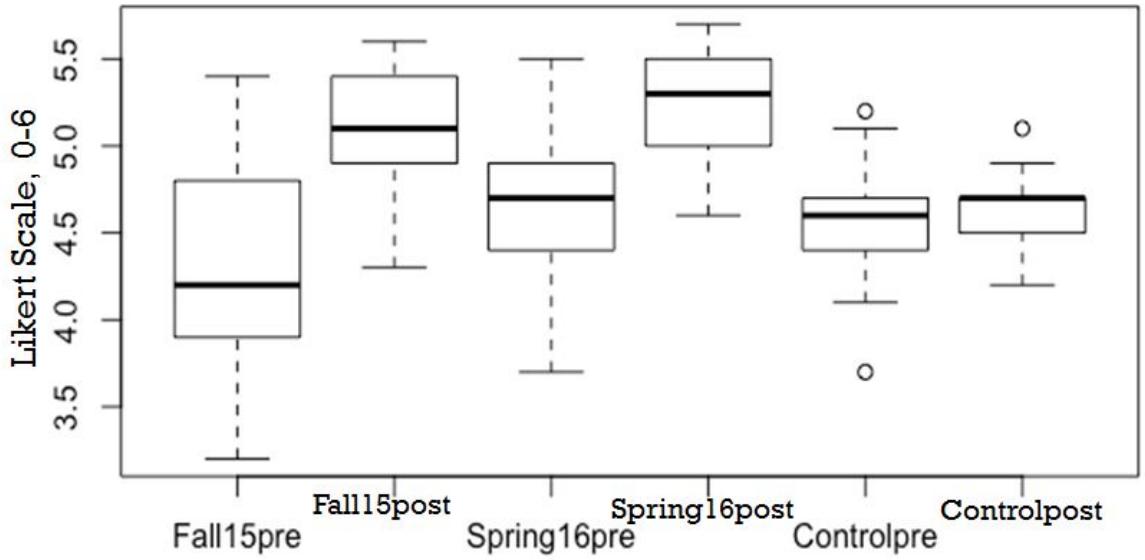

Figure 1 shows the average score from the pre and post surveys for both the experimental cohorts and the control cohort. 0 corresponded to not applicable, 1 to the least desirable answer and 6 the most desirable answer. Ranges and standard deviations are also shown.

Table 1

	Cohort1 Fall 2015 (n=22) Pre vs Post	Cohort2 Spring 2016 (n=21) Pre vs Post	Control (n=8) Pre vs Post
Overall	**+0.82** **(p < 0.05)**	**+0.57** **(p < 0.05)**	+0.08
Section 1 (Understanding)	**+0.73** **(p < 0.05)**	**+0.7** **(p < 0.05)**	+0.1
Section 2 (Skills)	**+1.1** **(p < 0.05)**	**+0.71** **(p < 0.05)**	**+0.27** **(p<0.05)**
Section 3 (Attitudes)	+0.78 (p=0.06)	**+0.43** **(p < 0.05)**	+0.13
Section 4 (Integration of Learning)	**+0.6** **(p < 0.05)**	+0.3 (p=0.058)	**-0.38** **(p<0.05)**

Table 1 shows the average increase or decrease in survey responses for both experimental cohorts and the control cohort. The average scores for the entire survey and the average scores for each section of the survey are shown. A shift towards a higher score would indicate that students were self reporting a higher level of comfort, skill or understanding in their responses to the questions. Statistically significant differences are highlighted in bold.

Discussion

The data presented above indicate a significant impact of this pedagogical approach on self-reported student learning in the areas measured. Increases of between a half and whole point on a six-point likert scale over the course of a semester were achieved. Not surprisingly, the largest impact was seen in the area of “Understanding" where survey questions were phrased “I understand how to… “(see Appendix A). For the vast majority of these students this set of modules added to BIO182 was their first ever exposure to an article directly from a primary journal, and the learning curve is undeniably steep as the format, vocabulary, conventions and grammatical conventions of this type of writing are all unfamiliar. Simply understanding how to approach this form of written communication takes some time and practice. By participating in multiple activities and assignments throughout the semester that were expressly designed to lead students through various methods for “decoding” scientific writing large gains were realized. However the survey also revealed that students reported significant and large gains in Skills and Attitudes, and were able to see the utility of these skills, as measured in the Integration of Learning survey section. The positive gains in attitudes and confidence are important in view of the high levels of attrition seen in the early years of STEM curriculum. In addition, the CREATE methodology may be particularly valuable in a community college setting to prepare students for the rigors of reading in upper division courses they will encounter post-transfer at a four-year institution.

An added benefit surfaced through the reading of four papers that, on the face of it had no connection (primate lice, fish parasites, tomato flavor, competition between lizard species; see Appendix A). This was that the unifying theme of evolution within biology was clearly displayed. Each paper contained significant discussion of the evolutionary process, often through DNA sequence analysis. The unity (yet diversity) of life, the shared genetic code and the modern use of DNA sequence analysis to determine relatedness was highlighted through these diverse papers. This is not particularly surprising to a biologist - as Theodosius Dobzhansky noted in his well known paper, “Nothing in biology makes sense except in the light of evolution”. But for these students just beginning their biological studies it was a powerful lesson in the importance of evolution to the field of biology.

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Coil D, Wenderoth MP, Cunningham M, Dirks C. Teaching the process of science: faculty perceptions and effective methodology. *CBE Life Sci Education* 2010; **9**:524-535.

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Acknowledgements

Many thanks to Danielle Carlock, Niccole Cerveny, Holly Harper, Jennifer Lane and Nicola Plowes - the 2015/16 MILRF fellows, and Amy Marin and Ramona Cox of MCLI, for many helpful discussions and fun experiences throughout this year long process. I would also like to acknowledge and remember Dr. Bryan Tippett for supporting my fellowship application and always championing research in its many forms. Finally, thanks to Ilse Kremer for running my control group at very short notice.

This work was supported by the Maricopa Center for Learning and Instruction (MCLI) MILRF program.

Appendix A: Papers used for modified CREATE process in BIO182

Pair of lice lost or parasites regained: the evolutionary history of anthropoid primate lice.

Reed et al., 2007. BMC Biology 2007 **5**:7

http://bmcbiol.biomedcentral.com/articles/10.1186/1741-7007-5-7

Genomic insights into the evolutionary origin of Myxozoa within Cnidaria.

Chang et al., 2015. PNAS **112:** 48 14912–14917

http://www.pnas.org/content/112/48/14912.abstract

Uniform ripening Encodes a Golden 2-like Transcription Factor Regulating Tomato Fruit Chloroplast Development.

Powell et al., 2012. Science **336**: 1711-1715

http://science.sciencemag.org/content/336/6089/1711

Rapid evolution of a native species following invasion by a congener.

Stuart et al., 2014 Science **346**: 463-466

http://lososlab.oeb.harvard.edu/files/lososlab/files/stuart_et_al._2014.pdf

Appendix B: Pre/Post Survey instrument

http://www.salgsite.org/instrument/preview/64783

Understanding

1. Presently, I understand...	not applicable	not at all	just a little	somewhat	a lot	a great deal
1.1 The following activities that will be explored in this class						
1.1.1 How to "concept map"	○	○	○	○	○	○
1.1.2 How to use sketching/cartooning to clarify how experiments or studies were done	○	○	○	○	○	○
1.1.3 How to "annotate figures"	○	○	○	○	○	○
1.1.4 How to work effectively in small groups	○	○	○	○	○	○
1.2 What motivates people to choose biology, psychology or chemistry research careers	○	○	○	○	○	○
1.3 How to critically evaluate experiments or studies proposed by others	○	○	○	○	○	○
1.4 How to look at data and figure out what question the study that generated the data was addressing	○	○	○	○	○	○
1.5 What researchers and scientists are like as people	○	○	○	○	○	○
1.6 I understand "the nature of science"	○	○	○	○	○	○
1.7 What words come to mind when you think about "scientists"?						

Skills

2. Presently, I can...	not applicable	not at all	just a little	somewhat	a lot	a great deal
2.1 Read and critically analyze science articles from the Internet/newspaper/magazines	○	○	○	○	○	○
2.2 Critically read and analyze journal articles (primary literature of science)	○	○	○	○	○	○
2.3 Identify patterns in data	○	○	○	○	○	○
2.4 Recognize a sound argument and appropriate use of evidence	○	○	○	○	○	○
2.5 Develop a logical argument	○	○	○	○	○	○
2.6 Cope with the complex language and jargon of scientific writing	○	○	○	○	○	○
2.7 Design a study or experiment that follows up on one I read about	○	○	○	○	○	○
2.8 What do you find the most challenging about the study of biology?						

Attitudes

3. Presently, I am...	not applicable	not at all	just a little	somewhat	a lot	a great deal
3.1 Enthusiastic about careers in biology and/or chemistry research	○	○	○	○	○	○
3.2 Interested in taking or planning to take additional classes in this subject	○	○	○	○	○	○
3.3 Confident that I can "decode" data presented in graphs, tables or charts	○	○	○	○	○	○
3.4 Confident that I can read and analyze primary literature	○	○	○	○	○	○
3.5 Confident that I can intelligently criticize others' ideas or proposals	○	○	○	○	○	○
3.6 Confident I can design a good experiment or study	○	○	○	○	○	○
3.7 What words come to mind when you think about "research careers?"						
3.8 Are you currently interested in a research career? (yes, no, maybe). Why or why not?						

Integration of learning

4. Presently, I am in the habit of...	not applicable	not at all	just a little	somewhat	a lot	a great deal
4.1 Connecting key ideas I learn in my classes with other knowledge	○	○	○	○	○	○
4.2 Thinking about whether I am fully understanding what I am reading	○	○	○	○	○	○
4.3 Thinking about "how I know what I know", while studying	○	○	○	○	○	○
4.4 Using a critical approach to analyzing data and arguments in my daily life	○	○	○	○	○	○