The current study addresses four assumptions connected to the National Science Education Standards (National Research Council [NRC], 1996, pp 28ff; Siebert, & McIntosh, 2001); what students learn is greatly influenced by how they are taught, the actions of teachers are deeply influenced by their perceptions of science as an enterprise and as a subject to be taught and learned, student understanding is actively constructed through individual and social processes, and actions of teachers are deeply influenced by their understanding of and relationships with students.
Effective undergraduate science teaching is a complex process requiring specialized knowledge and skills to do it well and facilitate student learning. Reforms in entry-level undergraduate science courses impact all students in higher education. There is a need to assure that science instructors transform science content knowledge and represent it in a way that promotes student learning with research based strategies (DeJong et al., 2005; Loughran et al., 2000; Sorensen, Evans, & Andersen, 2009; Van Driel et al., 1998). It is important to investigate current efforts underway in undergraduate science course reform. Investigation is needed of the knowledge faculty members have available to implement reforms that impact the course learning environment. There also is a need to study the impact of faculty reform actions on student outcomes in courses.

Science teaching requires specialized knowledge refined by faculty over time and through extensive experience (Loughran, Gunstone, Berry, Milroy, & Mulhall, 2000). We should expect to see differences among faculty instructors of science in our undergraduate science classrooms based on differences in their knowledge of teaching, its application to actual classrooms with students, and the institutional context in which faculty teach (Sorensen, Evans, & Andersen, 2009; Bland-Day, 1999). Lee Shulman (1987) stated that teacher development of specialized teaching knowledge is even more critical in inquiry-based classrooms. The knowledge of teaching science as opposed to a person’s knowledge of science, has a great impact on, and is particularly important to, the teaching and learning of science by students (Gess-Newsome, 1999; Magnusson et al., 1999; Mason, 1999; Morine-Dershimer, & Kent, 1999; Shulman, 1987).

Research literature describes the learning environment as having an effect on student approaches toward learning, which in turn, impacts student learning outcomes (Diseth, Pallesen, Brunborg, & Larsen, 2009, Kreber, 2002; Lizzo, Wilson, & Simmons, 2002). When students have a more positive perception of their learning environment, they are more likely to take a deep approach to learning as opposed to a surface approach. A deep approach to learning is an attempt to use evidence to understand the meaning of, and make connections between, the concepts being presented. A surface approach to learning means students memorize the content in order to pass the exam. A significant correlation exists between the learning environment and student learning, and/or their approaches toward studying (Biggs, 2001; Diseth, et al.; Trigwell & Prosser, 1991).

**Research Question**

Building on the existing research base, our study investigated undergraduate students’ perceptual understanding of the learning environment experienced in courses selected from a national population of higher education institutions. This study addressed the question, “*Do students perceive differences in the level of reform in their science courses?*” Since significant professional development efforts are underway to enable higher education faculty to reform undergraduate courses, it is important to investigate important variables related to the problem (Sunal, et. al. 2001). Students’ perceptions and preferences for their learning environment influence their learning in terms of content knowledge, literacy skills, and attitudes (Loyen, Remy, Rikers, & Schimdt, 2009).
The participating institutions, and one or more of their science courses, were involved in the NASA Opportunities for Visionary Academics (NASA/NOVA) faculty professional development program initiated in 1996 (NOVA, n.d.). The multifaceted NASA/NOVA program was designed to foster reform in higher education through the development and modification of entry-level, undergraduate science courses. The study’s population included teams of faculty from a diverse national group of 103 institutions that had undergone reform over a 10 year period in one or more of their undergraduate science courses. The population surveyed ranged from tribal colleges to Doctoral/Research universities-extensive (R-I) using the Carnegie (1994) classification (see Figure 1). A sample of faculty from nine of these institutions was selected to participate in the study reported in this paper (see Table 1). The content of the courses varied from Biology to Space Science as shown in Figure 2.

![Figure 1: Carnegie classification of the population of higher education institutions in the NASA/NOVA Program.](image)

The NOVA program invited the participation of undergraduate faculty concerned with improving entry level undergraduate science and mathematics courses between the years 1996 to 2006. Through NOVA, reform science courses were developed by collaborative teams of faculty in the sciences and education and centered on the NOVA course model using standards based guidelines proposed by the National Research Council (NRC) and the National Science Foundation (NSF) (NRC, 1996, NSF, 1996; Siebert & McIntosh, 2001). Participation in NOVA included opportunities for, and commitment to, enhanced knowledge and skills through workshops, exemplary higher education oriented standards-based instruction and course models, grant funding, mentoring, evaluation site visits, and collaboration within and between higher education institutions. The NOVA professional development model was delivered in three phases: (1) planning and preparation, involving training, collaboration, and action planning for addressing baseline needs in faculty skills and knowledge enhancement; (2) development and implementation, involving initial course change, action research, mentoring, and sharing of expertise; and (3) continuing development and long-term sustaining activity, involving action research, networking, monitoring including site visits, and dissemination (Sunal et al., 2004).
In a survey of the population from which the sample was selected, it was found that the learning environment in NOVA (reformed) courses at these institutions shared four common course features:

1) involving all students in an inquiry/investigative approach to learning science,
2) including fully integrated inquiry/investigative activities that involved the majority of a week’s class time,
3) using collaborative and cooperative learning groups during course activities, and
4) using continuous alternative assessment, rather than using only a few traditional exams. (Sunal et al, 2008a, Sunal & Sunal, 2008b; Sunal, Sunal, Sundberg, Mason, & Lardy, 2008c; Sunal et al., 2008d; Sunal et al., 2008e; Sunal, Sunal, Mason & Zollman, 2008f)

![Diagram of course content](image)

Figure 2: The diversity of course content included in this study and the content taught by the instructors.

Procedures

Pre- and post-testing along with on-site case study visits were completed with 33 faculty teaching entry level NOVA (reformed) and comparison undergraduate science courses at the 19 higher education institutions. The institution selection was based on the following criteria: (1) the NOVA course was still currently being taught, (2) the content being taught was science, (3) the NOVA reformed course still contained elements of the NOVA model, and (4) the course was required, or was an elective, in the program of study for elementary education majors. The innovations implemented in the NOVA reformed courses were based on the national science
standards. The changes made to the courses included, (1) changing the roles of faculty and students from instructor centered to student centered, (2) emphasis on inquiry-based pedagogy and class activities, and (3) more active student learning (Sunal, Sunal, Mason, & Lardy, 2008). The comparison courses were courses were taught by faculty who had not received professional development, or funding for course development, through the NASA/NOVA Program. The sample was geographically diverse, residing in nine states throughout the USA. The higher education institutions range in size from 4000 to over 40,000, with an average student population of about 13,000. Carnegie designations of the sample institutions are six Master’s degree granting institutions, two research doctoral granting institutions, and three minority designated Master’s degree granting institutions. The 19 NOVA undergraduate science courses included in the institutional sample had an average class size of 35 students with a range of 18 to 70 students. Several were one section of a multiple section course with their own lecture/lab/ and discussion periods. The course science disciplines included physics, astronomy, physical science, biology, integrated science, and geology.

Data Collection Instruments

Reformed Teaching Observation Protocol

The Reformed Teaching Observation Protocol (RTOP) was developed by the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) to measure the degree to which teaching in a science classroom is “reformed” (Piburn & Sawada, 2000; Sawada, 2000). The characteristics of reform measured by this instrument are based on national standards for mathematics and science education and research in mathematics and science education (Piburn & Sawada; Sawada). The RTOP gives insight into the instructor’s pedagogical content knowledge (PCK), course structure, and learning environment. The RTOP was used to score on-site observations of instructors’ teaching. Observations were made of all lecture, laboratory, and discussion sections that occurred during the week. Each section in the study was observed by more than one observer. After instruction occurred, observers collaborated to come to a consensus score. When agreement could not be reached, the scores were averaged.

The RTOP is divided into five subscales: (1) Lesson Design and Implementation, (2) Propositional Knowledge, (3) Procedural Knowledge, (4) Communicative Interactions, and (5) Student/Teacher Relationships. The Lesson Design and Implementation scale contains items such as, “In this lesson, student exploration preceded formal presentation”, and addresses how an instructor plans and implements a lesson to promote student learning. The Propositional Knowledge scale contains items such as, “The teacher had a solid grasp of the subject matter content inherent in the lesson”, and addresses how well the instructor understands the course content he or she is teaching. The Procedural Knowledge scale contains items such as, “Students made predictions, estimations and/or hypotheses and devised means for testing them” and is indicative of an instructor’s ability to select the appropriate teaching methods for the lesson being taught. The Communicative Interactions scale contains items such as “The teacher's questions triggered divergent modes of thinking” and indicates the types of discourse occurring in the classroom between students and the teacher and students with other students. The Student Teacher Relationship contains items such as, “The teacher acted as a resource person, working to support and enhances student negotiations” addressing the kind of relationship the teacher had
with the students in terms of knowledge control. An observer rates each item on the instrument as 0-4 (never occurred to very descriptive). To get the total or sub-scale scores, the ratings on the RTOP items included were summed. The scores were compared by creating a ranking of the total RTOP scores from highest to lowest and dividing the scores into three groups (1) higher, (2) medium, and (3) lower. The higher and lower group contained six instructors, and the medium group contained four instructors. (Piburn & Sawada, 2000; Sawada, 2000)

Constructivist Learning Environment Survey

The Constructivist Learning Environment Survey instrument (CLES) was developed by Peter C. Taylor and Barry J. Fraser in 1997 to enable teachers of science to monitor their constructivist approaches to teaching. The CLES was intended to allow teachers to understand their students' perceptions of the extent to which the classroom learning environment enabled them to reflect on their prior knowledge, develop as autonomous learners, and negotiate their understandings with other students. The instrument contains five scales; (1) the Personal Relevance Scale measures how relevant students feel the course content is to their lives outside of the classroom, (2) the Shared Control Scale measures students’ perceptions of their control over classroom learning, (3) the Critical Voice Scale measures students’ perceptions of their ability to question the teacher’s pedagogy, (4) the Student Negotiation Scale measures students’ perceptions of their ability to share their ideas with other students in the classroom, and (5) the Uncertainty Scale measures students’ perceptions of the level of inquiry based science knowledge in the classroom. Two versions of the instrument were given to the students during the semester. The pre-test first version involves participants in identifying the kind of classroom learning environment they prefer, as preferences or expectations, and is given during the beginning of the semester. The post-test second version involves participants in identifying the classroom experience they have had as they perceive that experience and is given at the end of the semester. The CLES was used to determine if there was a difference in student perception of traditional versus constructivist and inquiry-oriented teaching at the higher education level. Several examples of the use of the CLES to monitor the development of constructivist practices at the secondary level can be found in the literature. Emmett Wright (2008) used the CLES to monitor student perceptions of traditional (comparison) vs. constructivist (experimental) treatments in a higher education level environmental studies course. Significant differences were found between the two groups with the constructivist treatment group having a higher positive perception of the classroom environment as inquiry oriented at the end of the semester. Wright concluded his findings indicated that the experimental groups experienced more constructivist learning than the traditional groups. The instrument was used by Shin, Kim and Kim (2005) to measure students’ perceptions of the classroom environment before and after the implementation of a virtual reality module in an earth sciences class designed for pre-service teachers. Their results indicated this module increased students’ perceptions (ratings) of the classroom environment as facilitative, in particular on the shared control scale.

In this study, we used the CLES to examine students’ preferences (expectations) and perceptions of the learning environment in undergraduate science classes that had undergone reform under the NASA/NOVA program in a sample of higher education institutions as compared to non-reformed classes at the same institutions.
The CLES was given twice during the first week and during the last two weeks of the semester to undergraduate students in the selected courses at 11 institutions. The instrument was delivered on-line outside of the regular class time. After completing consent forms in class, students were instructed to respond to an e-mail providing the Internet URL where the CLES could be completed. Students who had not completed the instrument after a brief time were reminded on a periodic basis over a few days. Students’ data were stored electronically to be downloaded for analysis. The CLES uses a five point Likert-type scale with the categories of almost always (5 points), often (4 points), sometimes (3 points) seldom (2 points), and almost never (1 point). To measure differences in students’ perceptions of learning in their classes, students’ responses were summed to give a final score ranging from one to five. The scores were compared using the overall total score and then on the separate scales of the CLES. Reported here are differences in students’ overall perceptions of the classroom environment based on the level at which the instructor of their course implemented reform.

All analyses on the CLES and RTOP were conducted at the 95% confidence level using $t$-test, ANOVA, or univariate analysis of variance as indicated.

**Results**

**Instructor Quantitative Results**

Univariate Analyses of Variance determined that there were overall differences in RTOP scores between instructors teaching the reformed courses and instructors teaching the comparison courses $F(31, 1) = 7.39; p = .01$. This result was found with all scales of the RTOP except for the Propositional Knowledge Scale (see Table 1). The results indicate that the reforms implemented at the 19 institutions have been maintained over the years since initial participation in the NOVA professional development program. Differences in RTOP scores between the three groups were found on the overall score and on all scales except the Propositional Knowledge Scale.

**Table 1**

<table>
<thead>
<tr>
<th></th>
<th>$F$</th>
<th>sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL Score</td>
<td>7.385</td>
<td>.010</td>
</tr>
<tr>
<td>Lesson Design and Implementation</td>
<td>5.0</td>
<td>.030</td>
</tr>
<tr>
<td>Propositional Knowledge</td>
<td>3.8</td>
<td>.060</td>
</tr>
<tr>
<td>Procedural Knowledge</td>
<td>5.7</td>
<td>.020</td>
</tr>
<tr>
<td>Communicative Interactions</td>
<td>8.7</td>
<td>.006</td>
</tr>
<tr>
<td>Student Teacher Relationship</td>
<td>7.9</td>
<td>.009</td>
</tr>
</tbody>
</table>
Of the 19 institutions participating in the study, 9 institutions and 14 instructors generated usable student data from the CLES instrument. Because qualitative data indicated there were differences between the types of instruction observed in the classrooms of the 14 participants, the question was asked whether reform was implemented at different levels by the 14 participants. The participants were divided into 3 groups based on their instructor RTOP score. The five participants with the highest scores were placed in the high RTOP group, the five participants with the lowest scores were placed in the low group, and the remaining four were placed in the medium group. Analysis of Variance was used to determine if there were differences between the three groups of instructors. A One-way Analysis of Variance (ANOVA) indicated significant difference between the three groups on their overall RTOP scores ($F(2,11) = 57.4, p > .001$). Post-hoc results using the Bonferroni correction indicated that the three groups differed significantly from each other (see Figure 3).

![Figure 3: ANOVA and Post-Hoc Analysis using Bonferroni correction for Total RTOP score](image)

Significant differences were found on the Lesson Planning and Implementation Scales ($F(2,11) = 19.127, p > .001$). The instructor group implementing a lower level of reform was significantly different from the other two groups (see Figure 4). Instructors in this lower RTOP group were observed using teaching methods that engaged students in the classroom much less than the other two instructor groups.
Significant differences were not found between the groups on the Propositional Knowledge Scale ($F (2, 11) = 3.011, p = .091$) (see Figure 5). The observed instructors demonstrated an understanding of the concepts they were teaching regardless of the level of reform they demonstrated in their classroom.
The three instructor groups were significantly different from each other on the Procedural Knowledge Scale \((F (2,11) = 96.958, p > .001)\). The instructors in the higher level RTOP group were observed demonstrating an increased level of understanding of how to choose appropriate methods for teaching concepts than instructors in the lower group (see Figure 6).

**Figure 6:** ANOVA and Post-Hoc Analysis using Bonferroni correction for the Procedural Knowledge Scale

As shown in Figure 7, Significant differences were found between the three instructor RTOP groups on the Communicative Interactions scale \((F (2,11) = 79.469, p > .001)\). Less interaction between the students was seen in classrooms where a lower level of reform had been implemented. In these classrooms, communications tended to flow one-way from the teacher to the students, who took notes.

The level of reform implemented in the classroom was a significant factor in differences in scores on the Student Teacher Relationships Scale \((F (2,11) = 17.994, p > .001)\). Instructors implementing lower levels of reform in the classroom scored significantly lower on this scale (see Figure 8).
Figure 7: ANOVA and Post-Hoc Analysis using Bonferroni correction for the Communicative Interactions Scale

Figure 8: ANOVA and Post-Hoc Analysis using Bonferroni correction for the Student Teacher Relationships Scale.

**Instructor Qualitative Results**

Qualitative analysis, of narrative notes written during classroom observations and semi-structured interviews, indicated all instructors implemented reform in the classroom at different levels. The instructors implementing a high level of reform in their classroom, as measured
using the RTOP observation instrument, were instructors who participated in professional development, and were more likely to collaborate with others about their teaching. Statements from their interviews indicate they were highly reflexive about what, why, and how they taught, considering experience and science education research when formulating their beliefs and teaching practices.

Instructors in the medium RTOP group implemented an intermediate level of reform in the classroom. Instructors in this group tended to be interested in “trying new things” in the classroom. Their classroom practices generally were informed by personal experiences, though some may have been aware of educational research. When they were reflective, they tended to reflect on what should be taught and how it should be taught.

Interviews with instructors implementing a lower level of reform in the classroom, as measured using the RTOP, indicated they were more likely to hold traditional or behaviorist views of teaching and learning. They viewed the textbook as a good resource for student learning and a guide for the planning of their curriculum. They were less likely to collaborate with others about their courses, and participated less in professional development for teaching. If they were aware of educational research, they chose not to use it in the classroom or they tended to have a bleak view of it. When these instructors were reflective about their teaching, they tended to reflect on what should be taught.

**Student Results**

The purpose for the administration of Constructivist Learning Environment Survey (CLES) was to determine if students perceived differences in the level of reform in the classroom and if their perceptions of the learning environment were correlated with the level of reform observed using the RTOP. Students enrolled in reform courses should perceive their learning environment as being more constructivist than students enrolled in courses where instructors were observed and rated with a lower level of reform. Using the three instructor RTOP groups indicated above, it significant differences were found in the level of reform perceived by the students enrolled in the courses included in this study.

Figure 9 shows results using an ANOVA comparison of the total score on the post CLES instrument between the groups of instructors. A significant difference between the three groups was determined on the total post CLES score on the \( F (2,252) = 4.12, p = .02 \). A difference was seen between students enrolled in courses with an instructor rated with a higher level of reform and students enrolled in courses with a lower level implementation (Figure 7). A moderate correlation between level of implementation of reform and total score on the post CLES was found \( R = .171, p > .001 \). As more reform was implemented by the instructor, the higher student perception of a constructivist environment was noted on the CLES.
Figure 9: ANOVA and Post-Hoc Analysis using Bonferroni correction for total score on the post CLES

Sub-scale scores on the CLES also were examined. Differences were found on the relevance scale of the post CLES ($F(2,252) = 4.39, p = .01$). Post-hoc analysis using the Bonferroni correction determined that students in the classes with an instructor rated with a higher level of reform implementation differed from students enrolled in courses with instructors having a medium level of reform implementation (see Figure 10).

Figure 10: ANOVA and Post-Hoc Analysis using Bonferroni correction for the Relevance Scale on the post CLES
There was no significant difference for students on the Uncertainty Scale of the post CLES ($F(2,252) = 1.26, p = .29$) between the three instructor groups. This finding suggests that in the classrooms observed, students did not perceive the science content as being different or changing from other courses experienced (see Figure 11).

![Figure 11](image)

**Figure 11:** ANOVA and Post-Hoc Analysis using Bonferroni correction for the Uncertainty Scale on the post CLES

The students perceptions of the three instructor groups were not significantly different on the Critical Voice Subscale score ($F(2,252) = 3.21, p = .04$). The students were nearly equal in their perception of their ability to question the instructors’ teaching methods, course content etc. (see Figure 12).
The Shared Control scale rated by the students showed significant differences between the three instructor groups $F(2,252) = 3.61$, $p > .03$. Post hoc analysis found the students in courses with higher levels of reform implementation scored higher on the Shared Control scale than students in courses with lower levels of reform (see Figure 13). A weak correlation was seen between score on the Shared Control of the post CLES and the level of reform implemented by the instructor in the classroom $R = -.169$, $p = .009$. 

**Figure 12:** ANOVA and Post-Hoc Analysis using Bonferroni correction for the Critical Voice on the post CLES.
Figure 13: ANOVA and Post-Hoc Analysis using Bonferroni correction for the Shared Control on the post CLES

Significant differences between the three groups were found on the Student Negotiations scale ($F(2,252) = 5.41, p > .001$). Post-hoc analyses found that the students in courses with higher levels of reform implemented perceived higher levels of interactions with their peers than students enrolled in courses with instructors rated with lower levels of reform, RTOP scores. The results are shown in Figure 14. A moderate relationship was found between level of reform and the Student Negotiations Scale ($R = .5, p > .001$).

Figure 14: ANOVA and Post-Hoc Analysis using Bonferroni correction for the Student Negotiations Scale on the post CLES
To further examine the impact the level of reform implemented by the instructor has on student perception of the learning environment, the question was asked, “What score does a professor have to make in order for students to perceive the classroom environment as being different?” Univariate analysis of variance determined that an instructor would have to score above 71 ($F = (248,1) 4.5, p = .035$) or below a 45 ($F = (248,1) 5.1, p = .024$) in order for students to perceive the environment as different. A score of 71 indicates a very high level of instructor reform observed in the classroom. An instructor would have to score an average of 3 or above on every scale to achieve 71 or above. An average score of 45 or below is indicative of a very traditional classroom environment where the instructor takes up the majority of the classroom time and the focus is on instructor centered instruction.

The quantitative and qualitative results for instructors and students in entry level undergraduate science content courses indicate that the level of reform implemented in the classroom is an important factor in student perception of the learning environment.

**Conclusion**

The current study of a national and diverse sample of higher education institutions investigated faculty instructional patterns and the undergraduate student learning environment existing in entry level science courses. When comparing courses at 19 institutions, significant differences were found between the reformed science courses and comparison science courses. The RTOP scores in the reform courses ranged from 36-90 and the RTOP scores from the comparison courses ranged from 34-70. The results indicated that some of the comparison courses had more elements of reform implemented than the “reform” courses. This result was hypothesized as being a positive indicator of the success of the NASA/NOVA faculty development program. Many of the institutions reported that the reform courses prompted other courses to adopt the NOVA course model (NSF, 1996; NRC, 1996; Siebert & McIntosh, 2001). It also opened up the question as to whether students perceive differences in the level of reform implemented in their science courses and thus were provided with an alternative, more positive, learning environment.

Our results indicate undergraduate students perceive differences in their learning environment. The level of reform found in the courses varied along a continuum from reformed to traditional. The context significantly effected student perceptions of the learning environment. Faculty instructors who implemented reformed teaching in the reform courses were rated differently by their undergraduate students as having a more positive, constructivist, learning environment. An average RTOP score of 71 or above had to be achieved in order for students to perceive a more positive learning environment in the classroom and as being different from other science courses. An average RTOP score of 71 indicates a very high level of standards based constructivist reform observed in the classroom. In order for reform efforts to impact students’ perceptions of their learning environment, instructors have to make large changes in their courses to ensure the learning environment allows students to interact with the instructor, other students, and course materials in a way that engages their interest and higher level thinking skills. The resulting context allows students to begin to construct a deeper and more meaningful understanding of key science concepts in their classes. Reform at the undergraduate level cannot be something that is done for some content, but not others. Nor can it be something the instructor can demonstrate,
while the students watch. The students have to be active in their interactions in the classroom. The development of a learning community among students should be the goal of more effective faculty instructors.

Narrative descriptions of observations in courses where the instructor was rated above 71 on the RTOP instrument indicated that students spent the majority of the time interacting with each other to develop their own ideas about the content that they were learning, demonstrating student centered learning in an inquiry oriented environment. There also was extensive student to teacher interaction, but this interaction was different than lecturing to the students or giving them the “correct answers”. Instead, the instructor helped students analyze the evidence and they had to come up with a solution of their own to a problem with which they were engaged.

Narrative descriptions of observations in courses where the instructor was rated below 45 on the RTOP instrument typically describe an instructor who spent little time interacting with the students, and a class in which students rarely interacted with each other or the course material in meaningful ways. Instead, the instructor presented the content and the students took notes on the course material presented. A summary of observed common differences between courses with varying levels of reform implemented as based on instructor RTOP ratings is shown in Table 3.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Difference in Observations Between Classroom with High or Low Levels of Reform Implementation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common classroom observations in courses with higher levels of reform implementation</td>
<td>Common classroom observations made in both higher and lower reform implementation</td>
</tr>
<tr>
<td>• Extensive student-student interaction during the class</td>
<td>• Teachers used technology: smart boards, <em>PowerPoint</em> etc.</td>
</tr>
<tr>
<td>• Extensive teacher-student interaction during the class</td>
<td>• Content presented in both courses was current, appropriate, and accurate.</td>
</tr>
<tr>
<td>• Questioning used to engage students; encourage students to think critically</td>
<td></td>
</tr>
<tr>
<td>• Lectures short and provided in a “just in time manner” coordinated with students’ inquiry activities</td>
<td></td>
</tr>
<tr>
<td>• Lecture and laboratory integrated</td>
<td></td>
</tr>
</tbody>
</table>
The results from this study indicate the effort instructors make to allow students to experience inquiry based science in a standards-based constructivist learning environment is noticed by their students. Qualitative and quantitative results show differences in students’ perceptions of their learning environment and in their ability to learn science. These results also indicate that in order for reform to be effective, it has to be implemented purposefully and fully. Implementing one or a few elements of standards-based constructivist reform in an undergraduate science course may not be enough to significantly impact student learning. Future studies include determining the relationship between the level of reform implemented in the classroom and students attitude toward science and student understanding of course content.

Work on the research project was supported by a grant from the National Science Foundation, ESI-0554594, titled Undergraduate Science Course Reform Serving Pre-service Teachers: Evaluation of a Faculty Professional Development Model. The opinions expressed in this paper are those of the authors and do not necessarily reflect those of the Foundation. Correspondence should be sent to: Dennis Sunal, dwsunal@bama.ua.edu

Authors’ Notes

Erika Steele is a doctoral candidate at the University of Alabama. Erika received her Master's degree in Biological Sciences in 2008. She currently is a graduate research assistant under the direction of Dr. Dennis Sunal while she is completing her dissertation on learning environments in university science classrooms. Her focus is on how the instructional methods selected by the professor teaching the course impacts student perception.

Dennis W. Sunal holds a Ph.D. in science education, an MA in Interdisciplinary Science, and a BS in Physics all from the University of Michigan. He is a Professor of Science Education at the University of Alabama. His university teaching experiences include undergraduate and graduate courses in physics, engineering, curriculum and instruction, and science education. He holds both Secondary, 6 -12, and Elementary Kindergarten-6 teacher certification and has taught extensively on both levels. His research interests are in undergraduate science, pre-service teacher education, conceptual change in teachers and faculty, and web course design. He has been project director and co-director in numerous grants (e.g. NSF, NASA, Department of Education, USIA, and U.S. Department of Energy). Dr. Sunal has published numerous articles and chapters in refereed journals and books. Recent research presentations have been at the annual meetings of NARST, ASTE, NSTA, SCST, AACTE, and AERA. His published books include Teaching Elementary and Middle School Science; Integrating Academic Units in the Elementary School Curriculum; Reform in Undergraduate Science Teaching for the 21st Century; and The Impact of State and National Standards on K-12 Science Teaching, and The Impact of the Laboratory and Technology on Learning and Teaching Science K-16. E-mail: dwsunal@bama.ua.edu

Cynthia Szymanski Sunal is Professor of Curriculum and Instruction at The University of Alabama and Director of the Office of Research on Teaching in the Disciplines. She primarily works with elementary and middle school teachers. Among her publications are numerous books, journal articles, and monographs. She is Executive Editor of two journals and publishes a
research series. She has been involved in several funded projects from the National Science Foundation, the Department of Energy, and other agencies.

References


