The Impact of Science Education Reform on Students' Perceptions of the Learning Environment

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Abstract

Research has shown that the learning environment has an impact on the approach that students use to learn the course content (Diseth, Pallesen, Brunborg, & Larsen, 2009; Biggs, 2001; Trigwell & Prosser, 1991). When examining the impact of reformed science teaching at the undergraduate level, the question of how students perceive their learning environment arises. The current study of a small national and diverse sample investigated the learning environment existing in undergraduate entry level science courses with various levels of implemented reform. Results identified significant relationships between courses the level of reform implemented in the course and student perception of the learning environment. The level of reform found in the courses was found to vary along a continuum from reformed to traditional instructor orientation and this context significantly affected student perceptions of the learning environment. It was determined that, in order for students to perceive their learning environment as being different, an instructor would have to implement a significantly high level of reform. Qualitative and quantitative analyses revealed that the level of reform implemented in the classroom had a significant effect on how students felt about the control of their learning in the classroom and their abilities to share their ideas with others in the classroom. The abilities to be in control of how they learn course content and share their ideas with others may be important to help students develop a deeper understanding of the course content.

Undergraduate Science Course Reform: Impacts on Faculty and 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, using research based strategies, and represent it in a way to promote student learning (Sorensen, Evans, & Andersen, 2009; DeJong et al., 2005; Loughran et al., 2000; Van Driel et al., 1998). It is important to investigate current efforts underway designed to reform undergraduate science courses, the instructional changes made by faculty that impact the classroom learning environment, and the impact of such actions on student outcomes in those courses.

Background

This study addressed four assumptions connected to *the National Science Education Standards* (National Research Council [NRC], 1996; 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 in teaching science are deeply influenced by their understanding of and relationships with students.

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 context faculty find themselves in relating to their institution (Sorensen, et al., 2009). For those undergraduate science courses involved in reforms set in interpreting the guidelines of the *National Science Education Standards,* 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).

Literature Review

According to John Biggs and colleagues (2001), student learning outcomes were the result of the educational system in which the learning event was located as schematized in the Presage-Process-Product (3P) model shown in Figure 1. The 3P model describes how presage and process factors in a learning environment interact to form student outcomes, or products. Presage factors refer to characteristics in the students and instructor prior to the start of the learning event (Biggs et al, 2001). Students' prior knowledge, preferences for learning, and ability were formed prior to starting the course and each of these could impact students' ability to learn the content presented. Instructors' beliefs about teaching and learning, content selected to be taught, methods of teaching and assessment, and institutional factors also were considered to be pre-existent at the start of the course. Process factors were described as the characteristics of the activities intended for student learning that occur in the classroom. The factors in the 3P model interacted in a dynamic manner; that is, the model was not unidirectional. The products of learning impacted the presage and process factors (Biggs et al, 2001). An instructor may refine personal beliefs about teaching and learning (presage) as a result from student outcome (product) from an instructional methodology (process) used in the classroom. Students may take a surface approach to learning prior to starting the course (presage) but adapt a deep approach to learning in response to the learning activities in the classroom (process) and/or in response to their grades (product) from an learning activity (process) (Biggs et al, 2001). This study will focus on presage characteristic of perception of the learning environment and its impact on student learning.

Student learning occurs as a result of several factors such as student ability, student preconception of learning, instructors' beliefs about teaching and learning, and the type of instruction used in the classroom (Biggs et al, 2001). Research indicates a relationship between what an instructor does in the classroom and the study habits students adopt (Trigwell, Prosser, & Waterhouse, 1999). When an instructor adapts a teacher centered/information transmission approach toward teaching, students approach learning by memorizing the course content. Trigwell, Prosser, and Waterhouse did not find a relationship between student centered approaches toward teaching and learning the course content for understanding or a deep approach to learning, but found students took a less surface approach to learning. The lack of relationship found may have been due to participants' description of their teaching using a survey type instrument. The participants were not interviewed, nor were their classes observed. It was possible that several of the instructors indicating they used student centered approaches to teaching were not using student centered techniques in their classes.

Research also indicates a relationship between student perception of the learning environment and their performance in the course (Trigwell, et al., 1999). Students who perceive the course favorably tend to take a deeper approach to learning than students who perceive the learning as being unfavorable, often taking a surface approach to learning the course content (Entwistle & Entwistle, 2004). A study by Kim Hinge (2011), however, indicated students have the tendency to perceive coursework with high levels of reform unfavorably. The same phenomenon has been noted by others (Lake, 2001). The students participating in research conducted by Henige indicated they perceived they had learned less using problem based learning, even though the data collected by the researcher indicated otherwise. Other studies also found that students enrolled in active learning courses, whether they perceived the learning environment as favorable or unfavorable, believed they learned less in the more reformed sections of the course (Lake, 2001). The students participating in more reformed courses felt that the instructor was not teaching and they were not learning. The students participating in these studies had preferences for traditional teaching and learning that may have stemmed from years of teaching experienced in high school and/or college (Henige, 2011).

Developing an understanding of the aspects of the learning environment in reformed classes that students find favorable or unfavorable will provide information to help improve faculty development in creating reformed courses that students perceive the teaching and learning favorably. Helping students change their perception of what teaching and learning mean may improve science instructors' ability to implement reforms.

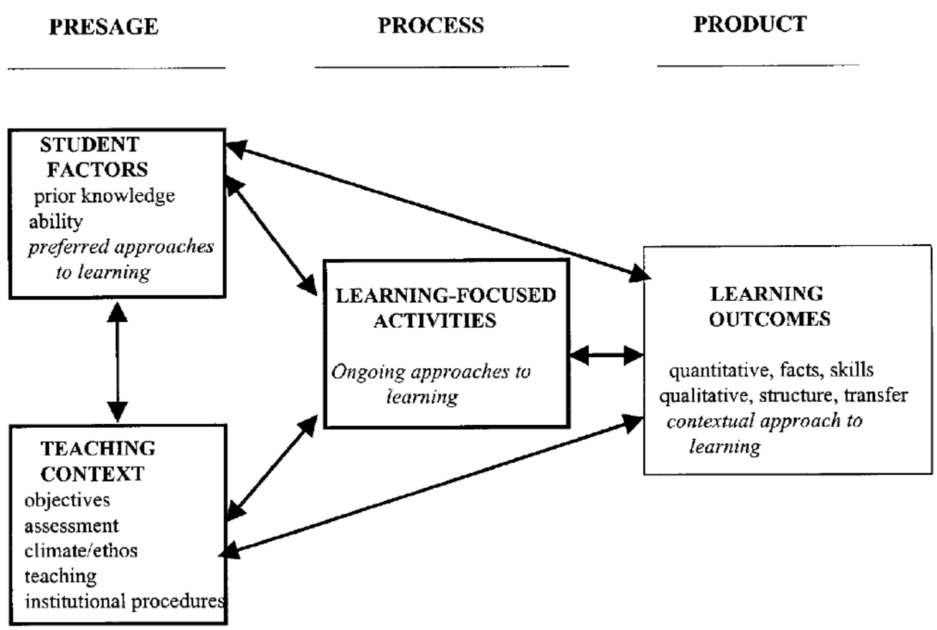


Figure 1: The Presage-Process-Product Model (Biggs, 2001)

Research Question

Building on the existing research base, our study investigated undergraduate student's perceptual understanding of the learning environment experienced in courses selected from a national population of higher education institutions. The 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, there is a critical need to investigate important variables related to the problem (Sunal, et. al. 2001). Students' perceptions and preferences for their learning environment influences their learning in terms of content knowledge, literacy skills, and attitudes (Loyen, Remy, Rikers, & Schimdt, 2009).

Study Population

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 1995 (NOVA, n.d.). The multifaceted NASA/NOVA program was designed to foster reform in higher education through development and modification of entry-level, undergraduate science courses. The study's population thus included faculty from a diverse national group of 103 institutions that had undergone reform over a 12 year period in one or more of their undergraduate science courses. The population (see Figure 2) surveyed ranged from tribal colleges to doctoral/research universities-extensive (R-I) using the Carnegie (1994) classification, see Figure 2. 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 4 courses varied from Biology to Space Science as shown in Figure 3.

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. Participation in NOVA included opportunities for, and commitment to, enhanced knowledge and skills through workshops, exemplary 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 reform 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,
4) using continuous alternative assessment, rather than using only a few traditional exams. (Sunal et al, 2008a, Sunal & Sunal, 2008b; Sunal, Sunal, Mason & Zollman, 2008f; Sunal, Sunal, Sundberg, Mason, & Lardy, 2008c; Sunal et al., 2008d; Sunal et al., 2008e).

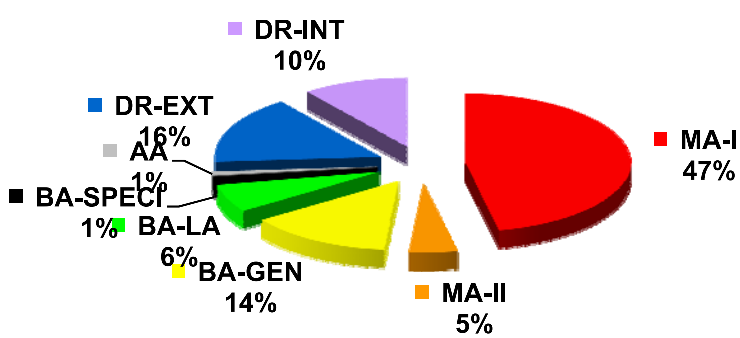


Figure 2: Carnegie classification of the population of higher education institutions in the NASA/NOVA Program.

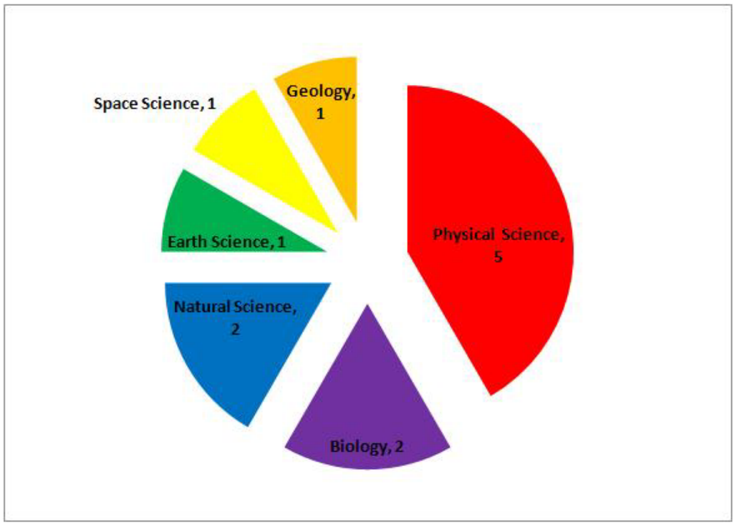


Figure 3: The diversity of course content included in this study

Procedure

Building on the existing research base, the study investigated the learning environment existing in undergraduate entry level science courses of a small national and diverse sample. The research design for this naturalistic study of a subset of the sample used qualitative and quantitative data to identify characteristics and relationships in the course instructional characteristics of undergraduate faculty and the perceptions of the learning environment of their students.

Pre- and post-testing, along with on-site case study visits, were completed with 33 faculty teaching entry level undergraduate science courses at the 19 higher education institutions from the original NASA/NOVA population of 103 institutions. The current study sample includes data from 9 of those institutions and 14 faculty members. The sample was geographically diverse, residing in nine states throughout the United States. The higher education institutions, universities and colleges, 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 MA granting institutions, two research doctoral granting institutions, and three minority designated MA granting institutions. The 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 single examples of 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 Developed by Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) to measure the degree to which a science classroom teaching is "reformed" (Sawada, 2000; Piburn & Sawada, 2000). The characteristic of reform measured by this instrument are based on national standards for math and science education and research in mathematics and science education (Sawada, 2000; Piburn & Sawada, 2000). The *RTOP* gives insight into the instructor's PCK, course structure, and learning environment. The *RTOP* was used to rate on-site observations of instructors' class sessions. Observations of all lecture, laboratory, and discussion sections that occurred during the week were made. Each observed section was reviewed by more than one trained observer. After instruction occurred, observers collaborated to come to a consensus rating. When agreement could not be reached, the ratings were averaged.

The instrument 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 they are 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" and addressed 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 -> very descriptive). To get the total *RTOP* ratings, the ratings on all of the items were summed. To get the rating on each scale, the ratings for each item on the scale was summed. The ratings were compared by creating a ranking with the total *RTOP* ratings from highest to lowest and dividing the ratings into three groups 1) higher, 2) medium, and 3) lower. The higher and lower group contained 5 instructors, and the medium group contained 4 instructors.

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 first version involves participants in identifying the kind of classroom learning environment they prefer and is given during the beginning of the semester, preferences or expectations. The 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, perceptions or perceptual understanding of experiences.

The *CLES* instrument has been 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. Wright (2009) 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 indicating that the experimental groups experienced more constructivist learning than the traditional groups. Shin, Kim and Kim (2005) used the instrument to measure student's perception 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 the present study, the *CLES* was used to examine students' preferences (expectations) and perceptions, perceptual understanding, of the learning environment in the sample of undergraduate science classes that had undergone reform under the NASA/NOVA STEM faculty professional development program in a population of 103 higher education institutions as compared to non-reformed classes at the same institutions. The NOVA courses, reformed courses in this study, were developed and offered regularly beginning in 1996 in a this professional development effort to create reforms in higher education undergraduate, entry-level STEM courses.

The CLES instrument was given twice during the first week and during the last two weeks the semester to undergraduate students in the selected courses at sample institutions. The instrument was delivered online 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 to complete the instrument. Students' data were stored electronically and could 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, the students' responses were summed to give a final score ranging from one to five. The scores among students were compared using the overall total score and then were compared 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.

Interviews and Focus Groups

Faculty course instructors were interviewed individually. Faculty interviews focused on their experiences related to planning, developing, and teaching the undergraduate science course. Questions also related to the purpose and rationale for teaching the observed science course lesson and how it related to other lessons recently taught. Current undergraduate students in the sample courses were interviewed in focus groups of four or five students. These interviews focused on students' understandings, opinions of, and perceptions about science, science courses at the college or university, the specific science course in which they were enrolled, specific lessons observed during the weeklong site visit, and views of science teaching. All interviews took place during site visits in the semester in which the courses were taught.

Results

Reformed Teaching Observation Protocol

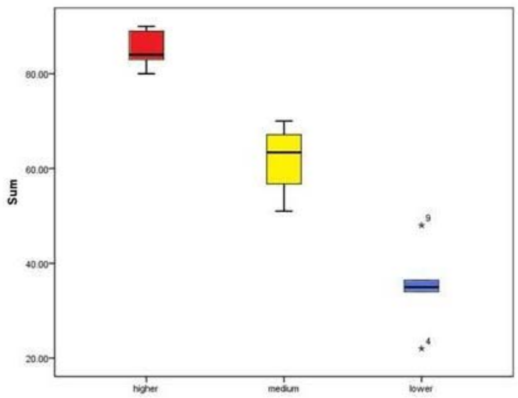
Overall, Univariate Analyses of Variance determined that there were differences in RTOP rating between faculty instructors who taught the reformed courses and instructors who taught the comparison courses $F(31, 1) = 7.39$; $p = .01$. This significance was found for all scales on the RTOP except for the Propositional Knowledge Scale. The results from this analysis are shown in Table 1. These results indicate that the reform implemented at the sample institutions have been maintained over the years since initial participation in the NASA/NOVA professional development program.

Table 1

Results from RTOP analysis

	F	*significance*
TOTAL Rating	7.385	.01
Lesson Design and Implementation	5.0	.03
Propositional Knowledge	3.8	.06
Procedural Knowledge	5.7	.02
Communicative Interactions	8.7	.006
Student Teacher Relationship	7.9	.009

Because quantitative and qualitative data analysis indicated differences between the levels of instructional reform observed in the classrooms of the participants, the question to be answered was how much reform was implemented at different levels by the 14 participants? The participants were divided into 3 groups based on their RTOP rating. The 5 participants with the highest rating were placed in the high RTOP group, the 5 participants with the lowest ratings were placed in the low group, and the remaining 4 were placed in the medium group. ANOVA was used to determine if there were differences between the three groups. Differences between the three groups were found on the overall rating and on all RTOP sub-scales except the Propositional Knowledge Scale. These results indicate the level of reform implemented in the classroom is a possible important factor in student perception of the learning environment.



(I)	(J)	Sig.
higher	medium	.002
	lower	.000
medium	higher	.002
	lower	.001
lower	higher	.000
	medium	.001

Figure 4: ANOVA and Post-Hoc Analysis using Bonferroni correction for Total *RTOP* rating

An One-way Analysis of Variance (ANOVA) indicated significant difference was seen between the three groups on their overall ratings on the RTOP ($F(2,11) = 57.4$, $p > .001$). Post-hoc results using the Bonferroni correction indicates that all three groups differed from each other. The results are shown in Figure 4.

Tests of Between-Subjects Effects

Dependent Variable:pRTOP71

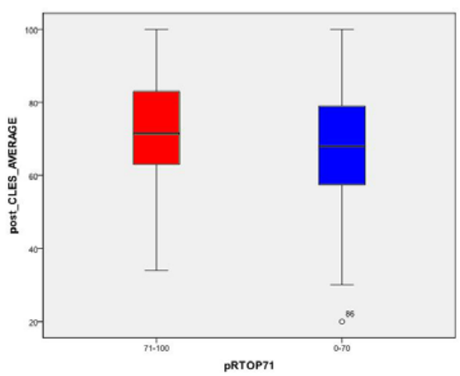
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.925[a]	1	.925	4.485	.035
Intercept	47.325	1	47.325	229.364	.000
post_CLES_AVERAGE	.925	1	.925	4.485	.035
Error	51.171	248	.206		
Total	778.000	250			
Corrected Total	52.096	249			

a. R Squared = .018 (Adjusted R Squared = .014)

Using the qualitative data portion of RTOP and the instructor's individual interviews, qualitative analysis indicated that the participants in the study implemented reform in the classroom at various levels. The instructors who implemented a high level of reform were instructors who participated in professional development and collaborated with others about their teaching. Statements from their interviews indicate they were highly reflective about what, why, and how they taught and that they considered experience and science education research when formulating their beliefs and practices. Data from interviews from instructors implementing a lower level of reform, with a low RTOP rating group, indicated that these instructors 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 to guide the planning of their curriculum. They generally did not collaborate with others about their courses, and rarely participated 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. If these instructors were reflective about their teaching, they tended generally focused on what should be taught, not on the instruction process. Instructors in the medium RTOP rating 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 were generally informed by personal experiences, though some were aware of educational research. When they were reflective, they tended to reflect on what should be taught and how it should be taught.

Constructivist Learning Environment Survey (CLES) Results

The purpose for the administration of CLES was to determine if students perceived differences in the level of reform in the classroom and if students' perceptions of the learning environment were correlated to the level of reform observed using the RTOP observation instrument. Univariate analysis of variance determined that an instructor would have to rating above 71 ($F = 4.5$, $p = .012$) or below a 45 ($F = 3.7$, $p = .027$) in order for students to perceive the environment as different. The results are shown in Figures 5 and 6 respectively. A rating of 71 indicates a high level of reform observed in the classroom. An instructor would have to be rated at an average of 3 or above on every item scale to achieve a rating of 71 or above. A rating of 45 or below, average rating on RTOP items of between 1 and 2 is indicative of a classroom where very little reformed teaching practices were observed.



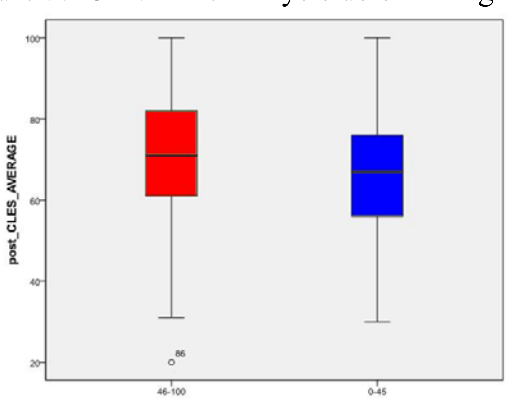
Tests of Between-Subjects Effects

Dependent Variable:post_CLES_AVERAGE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2301.071[a]	2	1150.536	4.526	.012
Intercept	34752.438	1	34752.438	136.723	.000
TOTAL_CLES_PRE	1294.600	1	1294.600	5.093	.025
High_Low	786.165	1	786.165	3.093	.081
Error	40923.191	161	254.181		
Total	836915.000	164			
Corrected Total	43224.262	163			

a. R Squared = .053 (Adjusted R Squared = .041)

Figure 5: Univariate analysis determining relationship of high *RTOP* rating and *CLES* score



Tests of Between-Subjects Effects

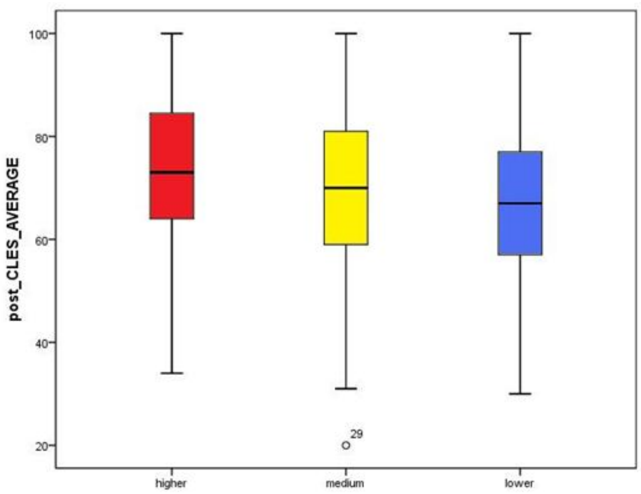
Dependent Variable:post_CLES_AVERAGE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1890.100[a]	2	945.050	3.681	.027
Intercept	33976.381	1	33976.381	132.341	.000
TOTAL_CLES_PRE	1313.998	1	1313.998	5.118	.025
Low_High	375.194	1	375.194	1.461	.228
Error	41334.162	161	256.734		
Total	836915.000	164			
Corrected Total	43224.262	163			

a. R Squared = .044 (Adjusted R Squared = .032)

Figure 6: Univariate analysis determining relationship of low RTOP rating and CLES score

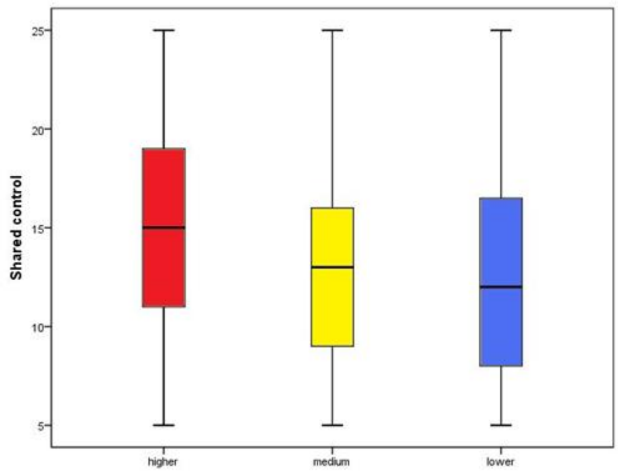
The *CLES* has 5 scales that measure student perceptions of the learning environment. The survey was designed with the intention that instructors use it to determine the degree to which students perceive constructivist teaching methods in the classroom. To answer the question which aspects of the learning environment does the implementation of reform impact the most, Univariate Analysis of Variance was used to determine if there were differences between students' scores on the scales on the *CLES* based on the instructors *RTOP* scores. The statistical analysis revealed that there were differences between instructors with 1) high RTOP scores (71 and above), 2) Medium RTOP scores (46-70), and Low RTOP scores (45 and below) on the Shared Control (F = 3.44, p = .02) and Student Negotiations (F = 22.44, p < .001) scales. One Way Analysis of Variance (ANOVA) using post hoc tests were run to determine where the differences between the three groups occurred. The results are shown in Figures 7-9.



(I)	(J)	Sig.
higher	medium	.193
	lower	.017
medium	higher	.193
	lower	1.000
lower	higher	.017
	medium	1.000

Figure 7: ANOVA and Post-Hoc Analysis using Bonferroni correction for total score on the post CLES

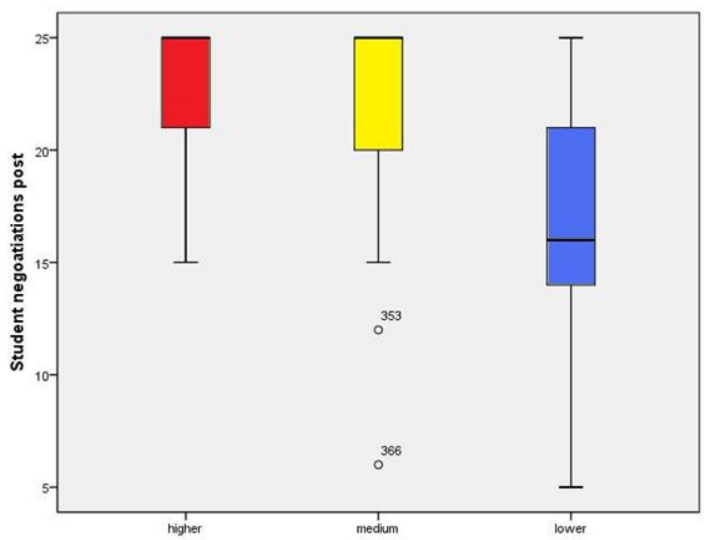
Figure 7 shows that a significant difference between the three groups was determined on the total score on the post CLES *(F*(2,252) = 4.12., p = .02). A difference was found between students enrolled in courses with a high level of implemented reform and students enrolled in courses with a lower level of implemented. A medium correlation between level of implementation of reform and total score on the post-*CLES* was found (R = .171, p > .001. The more reform implemented in the classroom, the higher the score was on the *CLES*.



(I)	(J)	Sig.
higher	medium	.302
	lower	.024
medium	higher	.302
	lower	1.000
lower	higher	.024
	medium	1.000

Figure 8: ANOVA and Post-Hoc Analysis using Bonferroni correction for the Shared Control on the post CLES

Post hoc analysis of the Shared Control Scale found that 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. The results are shown in Figure 8. A weak correlation was found between score on the Shared Control of the post *CLES* and the level of reform implemented in the classroom $R = -.169$, $p = .009$.



(I)	(J)	Sig.
higher	medium	1.000
	lower	.000
medium	higher	1.000
	lower	.000
lower	higher	.000
	medium	.000

Figure 9: ANOVA and Post-Hoc Analysis using Bonferroni correction for the Student Negotiations Scale on the post CLES

Significant differences between the three groups were found on the Student Negotiation scale (F (2,252) = 5.41, $p > .001$). Post-hoc analyses found students in courses with higher levels of implemented reform perceived higher levels of interactions with their peers than students enrolled in courses with lower levels of implemented reform. Differences were also seen between the low and medium groups. Students in the medium group perceived that they had more interaction with their peers than students in classes with a lower level of reform implemented. The results are shown in Figure 9. A high correlation level was found between level of reform and the Student Negotiations Scale ($R = .5$, $p > .001$).

Qualitative Analyses of Student Perception of the Learning Environment

Qualitative analyses of data from the RTOP narrative section, individual faculty interviews, and focus groups of students participating in each course was conducted to determine how differences in the level of reform in the learning environment may impact student perception of the learning environment. Qualitative analysis was used to provide details of the differences occurring in the classroom, and to provide corroboration, triangulation, that the students observed these difference as well as observed differences in the way they learned. The results of this analysis are summarized in Table 2.

Table 2

Participants in the Qualitative Analysis

Institution	**Instructor**	**RTOP Rating**	**Description of Instruction**	**Students Response to Learning Environment**
F	John	52	Faculty instructor stated that scientific investigation was the best approach to science teaching and learning; he used experimental designs to teach Newton's Laws and how these laws govern "flight"; he had students to make gliders in order to understand how Newton's Laws was related to flight; students worked in groups to construct their gliders; once gliders were constructed had to make predictions about whether or not their planes would "fly" or "glide" and why or why not; some of the gliders did not "fly" so student groups had to come up with hypothesis as to why their gliders failed; the faculty instructor was attempting to get students make a connection between what they have presumably read about the mechanism of flight and what they actually observe in the classroom	While the students enjoyed the hands-on activity in the class, they could not make a connection between the activities and the lectures. The students did not feel confident that they had learned the course material and wished that the instructor provided them with more closure.
	Angie	37	Angie was a new faculty instructor, and had only taught at the undergraduate level for ½ a year. The course, observed was her first teaching experience outside her experiences as a graduate teaching assistant.	The students felt that the instructional methods in the course helped them learn the course material. They all agreed that the course material made more sense after taking the course. The

			Angie used experiments, clickers, and questions to engage students in learning and found the large class size to be a barrier for providing students with a more authentic scientific experience. She did not feel that innovations could be effectively implanted in a large lecture format.	students participating in the focus group interview thought the lecture was more informative than the lab. The students could not see the relationship between the lecture and the lab.
G	Margie	80	Margie had been teaching undergraduate science for 19 years. Margie used hands-on methods in order to engage the students in science and to make it relevant to their lives. She believed her methodologies would help the students to lose their fear of science. Her goals for her students was that they gained a better understanding of the course content that they could take with them as they became science teachers.	The students felt that the course helped them learn the course material and felt confident that they could teach science. The students felt the instructor brought the concepts down to a level they could understand. They appreciated the various methods the instructor used in the class to teach the concepts.
	Carl	22	The instruction observed in Carl's class was very traditional. Carl attempted to engage the students through questioning, but did not give them enough time to answer the question or sensed their confusion and answered the question for them. The instructor tended to tell students what they needed to know instead of allowing the students to struggle and figure the answer out on their own. Carl seems to believe that by telling the students the material, they will learn it.	The students in this class were dissatisfied with both the lecture and lab portions of the course. They could not see how the lecture and lab were related. They did not like how the instructor only demonstrated one method of solving the problems in class. They also felt penalized for not solving the problem the way the instructor desired.
H	Bonnie	83	Faculty is a content specialist and stresses the importance of having to know science; Says you have to know the science content to be at ease in changing or modifying the curriculum to suit the needs of students; understands content should connect to other disciplines; emphasis on content being relevant and scientific literacy Used examples to represent phenomenon that are relevant to student lives/ takes into account prior knowledge; Use models to represent abstract concepts(e.g. circuits)/ Also aware of the various learning styles of	The students in this class felt that the instructional methods allowed them to develop an understanding of the course material that was better than they would have developed if the course was a pure lecture course. The students in this course felt confident in their in their learning of the course materials. The students appreciated the various methodologies used by the course instructor.

			his students; Used this strategy because it would enable students to conceptualize how circuits work. *"They need to know how to explain circuits, and to trouble shoot why things "go wrong*."	
	Lisa	93	Including her experiences as an undergraduate, Lisa had been teaching science at the undergraduate level for over 25 years. She spent significant amounts of time in professional development in order to improve her teaching skills. Due to her professional development experiences, she focuses on students developing process skills such inquiry over science content. The instructor stated that she focused on the ability to apply scientific knowledge rather than memorization of scientific facts.	The students in Lisa's course spoke positively of her class and other science classes at their institution. They felt that the science classes that they had taken had allowed them to see that science was relevant to their lives and not just something they read about in a textbook. The students in Lisa's class indicated they preferred the hands-on experiences that they were given in class because it allowed them to figure out the answers on their own . They also enjoyed being able to research and think like scientist.
M	Mike	85	Mike had been teaching science at the undergraduate level for 29 years and had been teaching the observed course for 10 years. Mike was a part of the original team receiving funding to reform the science course under the NOVA model. Mike is very interested in professional development to improve his instruction and stated that he attends every workshop that he can. He wanted his students to leave the course with an understanding of the basic concepts that the course covered. Because it was suggested by former students in the course, students are encouraged to go into elementary schools to teach the concepts covered in labs. He feels it provides them with the motivation they need to teach science. His priority is to give them the confidence they need to teach science. In order to help students learn, Mike used multiple teaching methods that he adjusted according to what he	The students appreciated the creative methodology used in the course because it allowed them to see that science was fun and they felt they were actually learning instead of just memorizing. They felt that Mike broke the concepts down into simpler forms that allowed them to understand them. They also felt the lessons were arranged so that everyone in the class understood the concepts after the lesson was complete. The class helped them think of more creative ways to teach science in the classroom instead of just using worksheets. Because they felt they learned the concepts, they felt they

			felt the students needed during the lesson.	could teach it better than if it were something that they just memorized. Mike was able to meet his students' preferences for the use of constructivist teaching methods in the classroom
	Tori	48	Tori had been teaching part time at the undergraduate level for 16 years. The only professional development she had participated in occurred during her time as a teaching assistant. Graduate school was when she discovered her love for teaching. At the time of the observation, she was still working on completing her PhD. She has had some courses dealing with education, but stated that she developed her understanding of teaching by watching other people. She wanted her students to understand the relevancy and importance of chemistry and develop the knowledge and skills they may need for subsequent courses. The instructor believed that 10% of the content can be made relevant, but the students were going to have to memorize the rest of the material. The instructor mainly used lecture to teach the content, but stated if she had time she would do group work, lab, and demonstrations.	The students found the note packets, homework, quizzes, and feedback to be helpful in their learning. They thought the on-line homework assignments were challenging in the beginning, but they enjoyed them after became used to their structure. They thought that seeing other students work the problems made it easier to believe that they can do the problems. All of the students agreed that having more time for lecture would beneficial because of the amount of work presented in the lecture.
N	Thomas	36	Faculty instructor saw the lab and lecture as two separate entities; He did the lecture portion of the class while his graduate teaching assistants facilitated the labs; Although the topics for both the lecture and the lab were the same the lab was not an extension of the lecture but rather was taught in isolation; The observed lectures were teacher-centered; the observed labs were traditional or "cookbook" labs	The students enrolled in the course expressed that they enjoyed being able to practice transforming the science lessons for elementary school students and the open ended projects and problems. They felt that they the most gained learning from those having to plan lessons to teach. The students described the instructor as being extremely helpful and willing to spend time to help them understand things they were confused about in the class. They also expressed that the

				lecture was too fast paced and that the only way they were able to understand was to ask the instructor questions after class.
O	Denise	90	This faculty instructor has had seven years teaching experience; She has a graduate degree in Science Education. Considers prior knowledge; Understands students have varied learning modalities; takes into account background and interest; uses activities that her students can use with their students; uses; web activities; emphasizes activities that can be used in elementary classrooms; The lesson observed was an introduction to plate tectonics; Six stations were set up in the lab for students to rotate to regarding: mantle, crust, and subduction; computer with the history of plate tectonics; earthquakes and the San Andreas fault & convection currents; computers dealing with the theory of plate tectonics (hot spots and back in time); Pangaea and continental drift; plate boundaries dealing with convergent and divergent movement; Although stations were set up for students, teacher spent a great deal of time providing background information to her students; Understands that her students lack science content knowledge regarding plate tectonics; encourages students to reflect on their learning	Students in the focus group believed that their experience of having to teach the content to others helped them develop their own understanding. In addition, the course instructor used the learning cycle when considering the preparing lessons for the students. In addition to being given hands-on experiences, the students were given closure to what they had learned and how the science content is connected to the activities.
	Darria	70	Darria had been teaching for 10 years and had taken many seminar courses to improve his teaching. Darria wanted to dispel the fear of science that students bring with them to his course and develop an understanding that science is all around them and relevant to their lives. Darria was very flexible in his teaching methods and made adjustments based on the response of the students. Her lessons were carefully designed to give the students the background information they needed to understand the concepts, explore the concepts using activities	The students in the class described having a low interest in science, but they enjoyed informal discussions dealing with science and reading about science in the news. The students felt the way the lessons were structured was very useful for their learning. They liked being provided with the background information before doing the hands-on activities. The felt that

			that were interwoven into the lecture and discussion sections as well as the lab, and to provide closure to ensure students understood the concepts.	even though the course covered a broad array of concepts, the course helped them understand the concepts and see the connections between all areas of science.
P	Dave	63	The instructor has not taken any formal courses on education but collaborates with faculty teaching the methods courses for education majors. The instructor participates in any professional development seminar offered by his college and department. The instructor wanted the students in his course to develop an appreciation for science as a way of knowing, and understanding the world in a way that other ways do not provide. The instructor used multiple methods to approach teaching the concepts so that students would gradually develop [problem solving?] skills. The instructor is aware of how prior knowledge can impact student learning so adjustments are made to adapt the lessons for each class	The students in Dave's class had mixed feeling about science. Most of them liked science, but they did not feel that could teach science. They felt uncomfortable by ideas in science that were abstract. The students had mixed feelings about the learning occurring in this class as well. Some of the students felt that they were learning better in Dave's class, other students described feeling as if they were being "taught", but they were not learning the concepts. The students also felt that he was not engaging as a lecturer and that he did not bring the concepts down to their level. They also felt that Dave attempts to cover too much information in the course. The students also expressed wanting to have more time in lecture to explain the concepts they covered in the lab: *" felt like don't understand unit, go to lab, do something gives better understanding. lecture is 50 minutes but doesn't give lot of time to explain"*

Qualitative Analysis of Instructors: Examples of Sample Cases

Qualitative Analysis of Instructors with High RTOP Ratings

Example sample cases (pseudonyms used) were described detailing the range of faculty responses from individual interviews, observational narrative statements from RTOP, and students' responses from class focus group interviews (also see Table 2).

Margie had been teaching undergraduate science for 19 years. Margie used hands-on methods in order to engage the students in science and make it relevant to their lives. She believed her methodologies would help the students to lose their fear of science. Her goals for her students were that they gained a better understanding of the course content which they could take with them as they became science teachers. Margie's rating using RTOP was 80.

Student focus group interviews indicate her students enjoyed the class more than they did other science courses taken in the past. They reported that she bought the concepts down to a level that they could understand and this allowed them to see how they could use the concepts they learned in class to teach elementary students. Students appreciated her use of manipulatives to start classes, allowing them to have hands-on experiences with materials, minds-on experiences with relationships between concepts, and collaboration with other students in the class. They also reported that the instructor always provided closure and prompt feedback. This allowed students to feel confident that they were learning, and understood what they needed to learn in order to develop a better understanding.

Mike had been teaching science at the undergraduate level for 29 years and had been teaching the observed course for 10 years. Mike was a part of the original team receiving funding to reform the science course under the NOVA model. Mike was very interested in professional development to improve his instruction and stated that he attends every workshop that he can. He wanted his students to leave the course with an understanding of the basic science concepts that the course covered. Because it was suggested by former students in the course, students were encouraged to go into elementary schools to teach the concepts covered in labs. He felt the experiences provided them with the motivation they neede to learn science. His priority was to give them the confidence they needed to learn science. In order to help students learn, Mike used multiple teaching methods that he adjusted according to what he felt the students needed during each class session. Mike's RTOP rating was 85.

The students supported the creative methodology used in the course because it allowed them to see that science was interesting and they felt they were actually learning instead of just memorizing. Students felt Mike broke the concepts down into simpler forms that allowed them to understand them. They also felt the lessons were arranged so everyone in the class understood the concepts after the lesson was complete. The education majors in the class reported that the instruction process helped them think of more creative ways to teach science in the classroom instead of just using worksheets.

Bonnie had been teaching for 6 years. Although she was not a part of the original NASA/NOVA team, she attended several professional development workshops geared toward science education reform. She stated in her interview, "I learn a lot from talking with colleagues and attending meetings that discuss science education reform." Bonnie also participated in extensive ongoing professional development that provided training in reform pedagogical practices. Bonnie stated that the reform course had been developed about 10 years ago, but had since changed. She stated that, prior to her teaching, the class it was a more traditional quantitative physics course. Her professional development experiences enabled to teach the course in a more reformed manner.

Bonnie believed the teacher's role in science teaching should be that of a facilitator. She used modeling as an instructional strategy to teach the concept of circuits to her class. Students developed focus questions, made predictions and claims, and provided evidence about the model credibility. She wanted students to be able to explain circuits as well as troubleshoot as to why circuits may or may not work. The instructor focused on the importance of students learning the concepts rather than students developing science inquiry skill or an ability to apply scientific knowledge. Bonnie's rating on the RTOP was 83. The undergraduate student focus group corroborated the statements put forth by Bonnie. The students reported that the instructional strategies employed helped them to understand the practicality of science concepts, the scientific process, and the mechanism by which circuits work in the manner that they do.

Including her experiences as an undergraduate, *Lisa* had been teaching science at the undergraduate level for over 25 years. She spent significant amounts of time in professional development in order to improve her teaching skills. Due to her professional development experiences, she focused on students developing science process skills such as inquiry over science content. Lisa stated that she focused on the ability to apply scientific knowledge rather than memorization of scientific facts. Lisa's rating on the RTOP was 93. The students in Lisa's course spoke positively of her class and other science classes at their institution. They reported that the science class had allowed them to see that science was relevant to their lives and not just something they read about in a textbook. The students in Lisa's class indicated they preferred the hands-on and minds-on problem experiences that they were given in class because it allowed them to figure out the answers on their own. They also enjoyed being able to research and think like scientist.

Denise had been teaching for 11 years. She was not a part of the original NASA/NOVA team but had taken several professional development workshops geared toward science education reform. Denise stated, in her interview, that it was important to model the teaching behaviors that she wanted her students to exhibit as future teachers. She believed inquiry-oriented instruction was the best approach to science teaching and learning. The observed lesson on plate tectonics revolved around six lab stations in which student groups visited to learn about some aspect of plate tectonics to include mantle, crust, subduction, Pangaea, and continental drift. She said that she chose those specific strategies because students have minimum content knowledge regarding plate tectonics and their short attention span requires the need for a variety of instructional strategies. Denise stated that these concepts were a part of the standards that would be covered in the elementary schools. Denise considered students' prior knowledge and learning difficulties regarding plate tectonics when planning the lesson. Denise's RTOP rating was 90. Students in the focus group believed that their experience of having to teach the content to others helped them develop their own understanding. In addition, the course instructor used the learning cycle when considering the preparing lessons for the students. In addition to being given hands-on experiences, the students were given closure to what they had learned and how the science content is connected to the activities.

Qualitative Analysis of Instructors with Medium RTOP Ratings

John had been teaching the undergraduate science reform course for over ten years. He believed that a hands-on experimental approach was the most appropriate for science teaching and learning. John received an observed RTOP rating of 52 on his observed lesson. Though the students said they enjoyed John's class and the instructor was helpful, a few expressed concerns that they were left on their own to form understandings of the concepts. They felt unsure of their learning the concepts in the course. Observations of the course indicated the students were engaged in the activity, but were not making connections between the activity and the concepts they learned prior to the observation. The instructor had hoped they would make the connections to the flight of paper gliders, and Newton's Laws. The students were not using Newton's Laws in their discussions, nor were they able to make the connections when probed by the observers.

Dave had been teaching at the university level for 26 years. He was a part of the original NOVA team and taught the course the entire 8 years it was available. The instructor had not taken any formal courses on education but collaborates with faculty teaching the methods courses for education majors. He participates in any professional development seminar offered by his college and department. Dave wanted the students in his course to develop an appreciation for science as a way of knowing, and understanding the world in a way that other ways do not provide. He used multiple methods to approach teaching the concepts so that students would gradually develop [problem solving?] skills. Dave is aware of how prior knowledge can impact student learning so adjustments are made to adapt the lessons for each class. The education majors in Dave's class had mixed feeling about science. Most of them liked science, but they did not feel that could teach science. They felt uncomfortable with ideas in science that were abstract. The students had mixed feelings about the learning occurring in this class as well. Some of the students reported that they were learning better in Dave's class, other students described feeling as if they were being "taught", but they were not learning the concepts. The students also felt that he was not engaging as a lecturer and did not bring the concepts down to their level. They also felt that Dave attempted to cover too much information in the course. The students also expressed wanting to have more time in lecture to explain the concepts they covered in the lab.

Tori had been teaching part-time at the undergraduate level for 16 years. The only professional development she had participated in occurred during her time as a teaching assistant. Graduate school was when she discovered her love for teaching. She has had some courses dealing with education, but stated that she developed her understanding of teaching by watching other people. She wanted her students to understand the relevancy and importance of chemistry and develop the knowledge and skills they may need for subsequent courses. Tori believed that 10% of the content can be made relevant, but students were going to have to memorize the rest of the material. She mainly used lecture to teach the content, but stated if she had time she would do group work, lab, and demonstrations. Tori's rating on the RTOP was 48. The students participating in the focus group interview all considered science to be something that they were interested in. Only one student felt disappointed with experiences in science at the university level. All students expressed the sentiment that science was the way we understand the world and the relationship between living and non-living things in the world and that their experiences at this institution allowed them to be able to see how the content they discussed in high school and previous grades could be applied to real life. The students found the note packets, homework, quizzes, and feedback to be helpful in their learning. They thought the on-line homework assignments were challenging in the beginning, but they enjoyed them after becoming used to their structure. They thought that seeing other students work the problems made it easier to believe that they can do the problems. All of the students agreed that having more time for lecture would beneficial because of the amount of work presented in the lecture.

Darria had been teaching for 10 years and had taken many seminar courses to improve her teaching. Darria wanted to dispel the fear of science that students bring with them to her course and develop an understanding that science is all around them and relevant to their lives. She was very flexible in his teaching methods and made adjustments based on the response of the students. Her lessons were carefully designed to give the students the background information they needed to understand the concepts, explore the concepts using activities that were interwoven into the lecture and discussion sections as well as the lab, and to provide closure to ensure students understood the concepts. Darria's rating on the RTOP was a 70. The students in the class described having a low interest in science, but they enjoyed informal discussions dealing with science and reading about science in the news. The students felt the way in which the lessons were structured was very useful for their learning. They liked being provided with the background information before doing the hands-on activities. They felt that even though the course covered a broad array of concepts, the course helped them understand the concepts and see the connections between all areas of science.

Qualitative Analysis of Instructors with Low RTOP Ratings

Angie was a new faculty instructor, and had only taught at the undergraduate level for one-half year. The course, observed was her first teaching experience outside her experiences as a graduate teaching assistant. Angie used experiments, clickers, and questions to engage students in learning and found the large class size to be a barrier for providing students with a more authentic scientific experience. Angie's rating on the RTOP was 37. Students enrolled in Angie's course felt science was difficult but interesting. The students reported that they felt they understood the course material better after participating in the course. The students participating in the focus group felt the lecture explained the course material better than the lab. They also felt that the lab and lecture were not related to each other.

The instruction observed in *Carl's* class was very traditional. Carl attempted to engage his students through questioning, but did not give them enough time to answer the question. He sensed their confusion and answered the question for them. Carl tended to tell students what they needed to know instead of allowing them to struggle and figure the answer out on their own. He seems to believe that, by telling the students the material, they will learn it, Carl's rating on the RTOP was a 22. Students in Carl's class did not feel the class or the lab were helpful in their learning. They said the lecture and lab were separate and not related to each other. The students indicated they wanted Carl to use more than one method to teach the concepts in the course. They also said Carl attempted to cover too much material for them to learn well. They thought Carl was more concerned with covering the material than he was with their learning of the material. The students enrolled in Carl's class had a lower preference for constructivist learning than students enrolled in other classes.

Thomas had been teaching undergraduate and graduate science courses for over 30 years and the undergraduate science reform course for 10 years. The course was structured in such a way that the lecture and lab were separate. Thomas taught the lecture portion of the lesson while graduate teaching assistants taught the labs. Thomas was observed twice in addition to lab observations. During his initial observed lesson, Thomas lectured the entire class period with little student-to-student or student-to-teacher interaction. During the second observation, he had the students role play the concept of respiration. He told the students exactly what to do and how to do it leaving little to no exploration on the part of the students. Thomas received a rating of

36 on all observed sessions. Thomas' course was structured similarly to a traditional biology class with a lecture and a lab. The students were given opportunities to use hands-on activities in the lab and participate in a weekly discussion group. However, at least from the lessons observed during the visit, these activities were all teacher centered. For example, during the discussion group, a learning opportunity for the students would have been to allow the students to come up with a way to demonstrate (or act out) glycolysis. In doing so, the students could have interacted with each other to gain a better understanding of the concept and the instructor could have seen where there were weaknesses in the students' understanding. The students in this course were rarely given the opportunity to interact with the science content on their own. Their inability to form a scientific concept or apply scientific knowledge may have been due to style of teaching and learning occurring in the classroom. The education majors enrolled in the course said they enjoyed being able to practice transforming the science lessons for elementary school students and the open ended projects and problems. They felt that they gained most from those having to plan elementary lessons to teach. The students described Thomas as being extremely helpful and willing to spend time to help them understand things they were confused about in the class. They also expressed that the lecture was too fast paced and that the only way they were able to understand was to ask the instructor questions after class

Conclusions and Implications

The current study of a small national and diverse sample investigated the learning environment existing in undergraduate entry level science courses. When comparing 14 undergraduate science courses at 9 different institutions, differences were found between the reformed (NOVA) courses and the comparison courses. Results involved data from faculty instructor RTOP ratings and individual interviews as well as students' completion of the CLES instrument and focus group interviews for each course.

The RTOP ratings in the reform courses ranged from 36-93, while the RTOP ratings from the comparison courses ranged from 22-70. On average, many of the comparison courses had fewer elements of reform implemented than found with the reform courses. We viewed this result as being a positive indicator of the success of the NASA/NOVA program. We have noted, in a previous study, that at many of the institutions reported, about one half, that the success of NOVA courses prompted other courses at the same institution to adopt the NOVA course model. It also opened up the question as to whether students perceive differences in the level of reform implemented in their undergraduate science courses.

Quantitative results indicated that there was a medium correlation between the level of implementation of reform, RTOP ratings, and total student score on the post CLES ($R = .171$, $p > .001$). There was a significant statistical difference in students' scores on the CLES between instructors with higher RTOP ratings and instructors with lower RTOP ratings ($F(2,252) = 4.12$., $p = .02$). The greater the implementation of reform, as evidenced in the RTOP ratings, in these undergraduate science classrooms, the higher the total rating of the involved students as measured with CLES. The results indicated that the level of reform had a significant impact on the Shared Control and Student Negotiation scales. Both of these scales were positively correlated with an increase in the level of reform implemented in the classroom. Mirroring this, results in this study identified relationships between the level of reform in the classroom and students' beliefs that they were able to learn the content. Students in the classes with higher levels of reform implemented expressed more confidence that they had learned the course's science concepts than students in classes with lower levels of reform. The students in classrooms with a high level of reform implemented often discussed the fact that they enjoyed their interactions with their classmates and their instructor. They found being able to share their ideas and seeing others share their ideas made them feel more confident in their scientific abilities because they were not only seeing the instructor do and talk about science. Students in one of the courses that had a low level of reform implemented expressed their discontent with feeling that the instructor did not respect the ideas of others and that they were only allowed to do the problems the way the instructor explained it. Many students enrolled in the courses with a low level of reform implemented expressed that they felt that science was over their heads or that science was interesting but they could not do it.

It also was determined that, in order for students to perceive differences in the learning environment, the faculty instructor chiefly responsible for the instruction in the undergraduate science course, would have had to be rated at 71 or above on the RTOP. A score of 71 or above indicates a significant amount of reform had to be implemented. An instructor would have to score at least a 3 on most of the 25 items. Students in courses with a score of 71 or above were exposed to science instruction that allowed them to share and explore their ideas with others, and build their understanding of science concepts through inquiry. The closer an instructors' RTOP observational rating was to 71, the more confident the students felt, as reported in student focus groups, that they had learned the course material or that they could learn the material.

A faculty RTOP rating below 45 had to be observed for students to perceive the learning environment to be different. A score of 45 or below indicated that very little reformed science teaching was observed. An instructor would have to get a score of 1 or 2 on all the items on the *RTOP*. Students in courses with a low score were likely to experience science as told to them through a lecture. They were likely not given chances to express and explore their ideas for themselves or with others in the course. The students were likely to express the perception, in student focus groups, that there was no connection between the lecture provided for them and the other activities that they do in the course. The more an instructor's RTOP rating was below 45, the more likely those students that they felt dissatisfied with the learning environment, and the more likely they were to express the sentiment that the course was not helpful in their learning.

Even if students felt they were learning, those in classes with faculty instructors having low RTOP ratings defined learning differently than students in classes with high instructor RTOP ratings. Students in classes with high RTOP instructor ratings were equally likely to mention their ability to understand the key concepts in the course, as they were to mention using higher order thinking skills. Students in classes with higher instructor RTOP ratings rarely mentioned tests, quizzes, and homework when discussing the instructor's methodologies. They usually described the course's hands-on activities and gaining the ability to solve problems. Students in the lower instructor RTOP rated courses described a need to understand and remember the content. When the students in low scoring classes felt the class was useful in helping them learn, they frequently mentioned homework, quizzes, and lecture notes.

A significant difference between instructors with high and low RTOP ratings was found on the student negotiations and shared control scales. The shared control scale indicated the amount of freedom students had to determine how their learning would occur. The student negotiation scale indicated how well students felt they were allowed to express their feelings to the instructor and other students. In focus groups, students in the courses with low instructor RTOP ratings often mentioned that their instructors only presented things one way. Some students even felt they were penalized for solving the problems in a different way. Students in courses with high instructor RTOP ratings, by comparison, described themselves as free to solve problems on their own.

Students in the courses with a high instructor RTOP ratings, and so, a high level of reform, expressed the sentiment that the instructor provided them with feedback and closure. The instructor explained how the hands-on activities were connected to the lecture, other disciplines, or their lives. In some of the courses with medium RTOP ratings, the connection between the activities and the lab were missing. In most of the courses with low RTOP ratings, the connection between lecture and lab was not there.

Our results indicate that students perceive differences in their learning environment. The level of reform found in the courses was found to vary along a continuum from reformed to traditional and this context significantly affected student perceptions of the learning environment. Faculty instructors who implemented reform in undergraduate science course(s) were rated as having a more positive learning environment by their students than were other faculty. A rating of 71 or above had to be achieved in order for students to perceive the reform implemented in the classroom as being statistically different from other undergraduate science courses. A rating of 71 indicates a high level of reform was observed in the classroom. An instructor would have to rate, on RTOP, an average of about 3 on every scale to achieve a rating of 71. The results for this sample of undergraduate courses indicates that, in order for course reform efforts to impact student perception of their learning environment, instructors had to make large efforts to ensure the learning environment allowed students to interact with the instructor, other students, and with course content and materials in a way that strongly engaged their interest and participation and allowed them to begin to construct a more meaningful scientific understanding of discipline content. It is what students do, not what is done to them, that made a difference. Reform that created significantly positive learning environment for students in these undergraduate science courses was not piecemeal nor selective of some elements. Reform involved several key elements and was deep, not surface. Reform was not something that the instructor demonstrated, while the students watched. The students had to be active in their learning interactions in the classroom.

Observations of courses where instructors were rated above 71 on the RTOP found students were spending the majority of the time interacting with each other and with materials or minds-on problems to develop their own ideas about the content that they were learning. There also was extensive student to teacher interaction, but this interaction was different than lecturing to the students or giving them the correct answers. The instructor, instead, helped students analyze the evidence and come up with solutions to problems on their own. In courses that were rated 45 or below, the instructor spent little time interacting with the students, and students interacted much less with each other or the course material. Instead, the instructor presented the content, and the students took notes on the course material presented. Other differences between courses with a high level of reform and a low level of reform as observed using the RTOP ratings and observational narrative are indicated in Table 3.

The 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). When students have a more positive perception of their learning environment, they are more likely to take a deep approach to learning attempting to use evidence to make connections between the concepts being presented. The results from this sample of courses indicate that, in order for reform to be effective, it needs to be implemented appropriately. Implementing some elements of a reformed course may also, not be enough to impact students in a significant way. Future studies include determining the relationship between the level of reform implemented in the classroom and other student outcomes, attitude toward science, and student understanding of course content.

Table 3

Difference in Observations Between Classrooms with Varying Levels of Reform Implementation.

Common classroom observations in courses with higher levels of reform implementation	**Common classroom observations of undergraduate science classrooms**	**Common classroom observations made in courses with lower levels of reform implementation**
• Extensive student-student interaction during the class • Extensive teacher-student interaction during the class • Questioning used to engage students; encourage students to think critically • Lectures short and provided in a "just in time manner" coordinated with students' inquiry activities • Lecture and laboratory integrated	• Teachers used technology: clickers, PowerPoint etc. • Content presented was current, appropriate, and accurate.	• Little requested, or planned, student-student interaction • Teacher lecture took up majority of the time • Teacher asked rhetorical questions; little wait-time for student answers • Students appeared bored and unengaged with the teacher and content • Lecture and laboratory separated in time

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