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Science Laboratory Experiences of High School Students Across One State in the U.S.: Descriptive Research from the Classroom.

This study examined the science laboratory experiences of high school students in Utah.

Introduction

The National Research Council's (2005) publication *America's Lab Report: Investigations in High School Science* provided the impetus for this study. In the NRC report, the experiences of high school students nationally are described along with recommendations for improving and supporting these experiences. Since the NRC report was published and this research project was initiated, science laboratory experiences for students have received still greater prominence in the U.S. as leaders of the National Science Teachers Association (NSTA) testified to the U.S. House of Representatives Subcommittee on Research and Science Education. Linda Froschauer, current NSTA President, articulated the organization's strong commitment to laboratory experiences stating that "Science educators are firmly committed to the role of the laboratory in the teaching and learning of chemistry, physics, biology, and earth sciences" (Froschauer, 2007, p. 2). Froschauer further emphasized the importance of laboratory experiences by referring to leading science and science education organizations proclamations regarding the importance of laboratory experiences, stating:

> The American Chemical Society is similarly committed to quality laboratory experiences: their *Guidelines for the Teaching of High School Chemistry* states "the laboratory experience must be an integral part of any meaningful chemistry program. ACS recommends that approximately thirty percent of instructional time should be devoted to laboratory work."
>
> The American Association for the Advancement of Science Project 2061 *Designs for Science Literacy* states "Learning science effectively … requires direct involvement with phenomena and much discussion of how to interpret observations.
>
> Both NSTA and the NRC believe that quality laboratory experiences provide students with opportunities to interact directly with natural phenomena and with data collected by others. Developmentally appropriate laboratory experiences that integrate labs, lecture, discussion, and reading about science are essential for students of all ages and ability levels. (Froschauer, 2007, p. 2)

At a time when science education is continually being shaped by research in teaching, learning, and cognition, science laboratory experiences seem poised as the vehicle through which reform efforts are most readily facilitated.

Beyond this testimony and the belief in the importance of science laboratory experiences for students expressed by the ACS, AAAS, and the NRC, the NSTA has recently revised and published a new position statement titled *The Integral Role of Laboratory Investigations in Science Instruction*. This position statement states:

> For science to be taught properly and effectively, labs must be an integral part of the science curriculum . . .NSTA strongly believes that developmentally

> appropriate laboratory investigations are essential for students of all ages and ability levels …
>
> Inquiry-based laboratory investigations at every level should be at the core of the science program and should be woven into every lesson and concept strand (NSTA, 2007).

This research was initiated and conducted in Utah where science education leaders have expressed a commitment to science laboratory experiences aligned to those articulated by these leading science organizations. Utah is not unique in its interest in science laboratory experiences for students. Most other states nationally, as well as most nations globally, have long been proponents of science laboratory experiences.

While the National Research Council's (2005) report provides important information about science laboratory experiences occurring in schools nationally and guidance for improving these experiences, the review of the research evidence for synthesizing this report was drawn from the following three strands: 1) cognitive research, 2) research into stand alone labs, and 3) research projects sequencing laboratory experiences within the science instructional unit. Very few research projects have been undertaken on a large scale spanning a significant geographic area to provide an account of the actual experiences of high school students. The science education leaders of Utah recognized the limited amount of data available to describe the actual experiences of high school students, and more specifically, the lack of data available in Utah that could be used to plan supportive initiatives for ensuring the quality of these experiences. This research sought to address this deficiency by employing both quantitative and qualitative methods to illuminate students' experiences in science laboratories, as well as the perceived needs of teachers facilitating them. Just as Utah science education leaders saw this research as the initial step in the process of helping committed science teachers continually improve laboratory experiences, it can also serve to focus and direct other states and nations in appraising and improving their own students' experiences.

Science Laboratory Literature

At a time when science education is continually being shaped by research in teaching, learning, and cognition, science laboratory experiences seem poised as the vehicle through which reform efforts are most readily facilitated. Historically, science laboratory experiences have been seen as venues for illustrating, demonstrating, and verifying known concepts and laws (Hofstein & Lunetta, 1982; NRC, 2005). While this historical vision for science laboratory experiences was tied to the beliefs about teaching and learning practiced at that time, these same approaches are out of step with current research on teaching, learning, and design principles that have revealed promise for increasing the effectiveness of laboratory experiences.

Reform efforts in science education emphasize engaging students in experiences as opposed to rote demonstrations. This is facilitated through engaging students in inquiry experiences. The National Science Education Standards describes inquiry experiences as those that allow students to "describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others" (NRC, 1996, p. 2). Research into teaching and learning, as well as leading national science education organizations, support a shift in science instruction that moves away from laboratory experiences that illustrate, demonstrate, and verify known concepts, and moves towards inquiry experiences (AAAS, 1993; Chang & Mao, 1999; Ertepinar & Geban, 1996; Hakkarainen, 2003; NRC, 1996; NRC, 2005; NSTA, 1998; Schwartz, Lederman , & Crawford, 2004). Not only have leading national science education organizations called for inquiry instruction, they have gone so far as to recognize and promote student inquiry in the science classroom as a central strategy for instruction at all grade levels (AAAS, 1993; NRC, 1996; NRC, 2005; NSTA, 1998, NSTA 2007). This shift has been fueled by research into inquiry instruction which has revealed great promise for increasing students' understanding of science (Chang & Mao, 1999; Ertepinar & Geban, 1996; Hakkarainen, 2003), understanding of the nature of science (Schwartz,

Not only have leading national science education organizations called for inquiry instruction, they have gone so far as to recognize and promote student inquiry in the science classroom as a central strategy for instruction at all grade levels.

Lederman , & Crawford, 2004), and increasing students' interest and attitudes toward science (Cavallo & Laubach, 2001; Chang & Mao, 1999; Paris, Yambor, & Packard, 1998).

The National Research Council's (2005) report heightened the science education communities' focus on laboratory experiences. This report called for increased focus on these experiences with regard to the type of experiences most often afforded to students. While care was taken to refrain from using this report as a means of condemning those involved in ensuring that effective laboratory experiences are provided to high school students, many of the findings that emerged presented a less than satisfactory assessment of current conditions. The following are highlights of this less than satisfactory assessment:

- The quality of laboratory experiences is poor for most students … access to any type of laboratory experience is unevenly distributed.
- Most students, regardless of race or level of science class, participate in a range of laboratory experiences that are not based on design principles derived from recent research in science learning. (NRC, 2005, p. 197)

Traditional approaches to science laboratory experiences were offered as an explanation for these less than satisfactory conditions. These traditional approaches were described as experiences that, among other things, are rarely designed to integrate learning of the content of science with learning about the process of science (NRC, 2005). Not only have traditional laboratory experiences focused on instructional strategies that are less likely to increase the effectiveness of laboratory experiences, the design principles typically employed did not align with research on cognition and learning.

Teacher interviews revealed little about students framing research questions or designing their own experiments.

Based on this literature and the recognized need for an appraisal of the actual science laboratory experiences of high school students, the following questions guided the research completed in Utah:

1. What are the experiences of high school students in science laboratories across the state?
2. What differences in science laboratory experiences, if any, are occurring between schools serving differing racial, ethnic, and socio-economic groups?
3. What are the perceived needs for improving science laboratory experiences for our state's high school students?

Research Method

Both quantitative and qualitative methods were chosen for this research. These methods were deemed fit for this inquiry because a straight forward description of the phenomena being studied—science laboratory experiences—was desired (Sandelowski, 2000).

The Context and Participants

Two groups of participants were selected to participate in this research. The first group of participants was drawn from a stratified random sample. The stratified random sample was used in an effort to obtain as representative a sample of (9-12) science teachers across the state as possible, given the resources and budget available. District size, diversity, and the socioeconomic status of the students served were the three factors used to stratify the forty school districts found in Utah. More specifics of the sampling can be found in Table 1. After schools were categorized and placed in Table 1 according to these three characteristics, the sample was obtained by randomly selecting two districts from each cell. This facilitated the selection of 12 districts. Within each selected district, two schools serving 9-12 students were randomly selected. Up to five teachers were randomly selected as possible participants and requests were made for a classroom observation of one class period while selected teachers were facilitating science laboratory experiences.

Because all schools serving students with 9-12 students were included in the random selection process, in the end 12 districts participated. Within these districts, 15 high schools, 1 K-12 School, and 3 junior high schools participated.

The second group of participants for the research was drawn from a request to all 9-12 science teachers in Utah to participate. This second group completed a questionnaire/ needs assessment that was used to triangulate the findings from classroom observations and teacher interviews emerging from the stratified sampling. Data emerging from this second group were also used in conjunction with the teacher interviews to reveal teachers' perceived needs for improving science laboratory experiences.

Table 1: District Categorization and Numbers of Districts in each Category

	Small (Less than 12,200 Students)	Large (Greater than 12,200 Students)
Low Diversity (Greater than 85% White Student Population)		
High Socioeconomic Student Population (Less than 39% Free-Reduced Lunch)	10 Disticts	7 Districts
Low Socioeconomic Student Population (Greater than 39% Free-Reduced Lunch)	15 Districts	0 Districts
High Diversity (Less than 85% White Student Population)		
High Socioeconomic Student Population (Less than 39% Free-Reduced Lunch)	2 Districts	0 Districts
Low Socioeconomic Student Population (Greater than 39% Free-Reduced Lunch)	2 Districts	4 Districts

Research Methods and Instruments

Classroom Observations and Teacher Interviews

Classroom observations and teacher interviews were used to illuminate the high school students' experiences in science laboratories across the state and any differences in these experiences occurring between schools serving differing racial, ethnic, and socioeconomic groups. The teacher interviews were also used to reveal teachers' perceived needs for improving science laboratory experiences for high school students. The forty teachers drawn from the stratified random sample participated in these classroom observations. Once classrooms were selected, the three research project team members completed the classroom observations and teacher interviews.

The Reform Teaching Observation Rubric (RTOP) (Piburn, Sawada, Falconer, Turley, Benford, & Bloom, 2000) was used by the research project team members to complete classroom observations. The RTOP is an instrument constructed to measure "reformed" teaching as described by the national science standards documents (AAAS, 1989; NRC, 1996). The theoretical constructs guiding the design of the instrument, along with reliability and validity information and results of an exploratory factor analysis of the RTOP, can be found in Piburn et al. (2000). Because the RTOP was created using the national standards documents in science, it was found to be aligned to the recommendations for improving science laboratory experiences in the National Research Council's (2005) report.

To become familiar with the RTOP instrument, the research project team members participated in a one day training session with a competent trainer/researcher experienced in using the instrument. The three project team members established inter-rater reliability with the RTOP through trial ratings of videocassettes from classrooms instructed by teachers not participating in the project. Inter-rater reliability was established at two stages in the project, once before beginning classroom observations and again at the halfway point in the classroom observation window. At each stage inter-rater reliability was determined to be at or greater than .80.

Teacher interviews were completed by the three research project team members using a teacher interview protocol constructed to guide the interviews. All forty teachers, who agreed to participate in the classroom observations, participated in the teacher interviews.

Questionnaire/Needs Assessment

The Questionnaire/Needs Assessment was used to triangulate findings regarding the high school students' experiences in science laboratories across the state, and any differences in these experiences occurring between schools serving differing racial, ethnic, and socioeconomic groups. Additionally, it was used in conjunction with the teacher interviews to reveal teachers' perceived needs for improving science laboratory experiences for high school students. The Questionnaire/Needs Assessment was delivered online as the online survey URL was sent through email invitation to teachers from 39 of the 40 school districts or 693 (9-12) science teachers. Of the 679 teachers that were sent the request to participate and whose e-mails were not returned, 211 teachers participated. This number represented a 31% response rate for the instrument (211/679). This response rate, while not high, is considered acceptable with 31% being the average rate for online surveys (DIIA, 2007). It is also important to note that teachers from 32 of the 39 districts surveyed did participate, signifying a high proportion of the districts were included.

Data Analysis

RTOP

Descriptive statistics of RTOP scores from all classroom observations were first used to reveal the students' science laboratory experiences across the state. The scores for the RTOP were then separated into the different subscales of the RTOP to reveal more about students' experiences. Statistical analysis was then completed to reveal whether statistically significant differences occurred when comparing the different subscales of the RTOP.

Because the RTOP was used as a key indicator for revealing high school students science laboratory experiences, comparisons of scores were used to investigate the extent to which differences occurred between schools serving differing racial, ethnic, and socioeconomic groups. This was completed by first determining whether or not statistically significant differences occurred between classrooms observed based on the three factors investigated (district size, district socioeconomic groups served, and district diversity indicators). Descriptive statistics and results of these statistical analyses were determined for each of the three factors, while a series of independent-samples *t*-tests were also conducted for each outcome variable from the RTOP for each of the three factors.

Many teachers have some reservations about the extent to which they feel prepared to lead students in laboratories, to emphasize science process alongside science content.

Teacher Interviews

In illuminating the high school students' experiences in science laboratories across the state and revealing teachers' perceived needs for improving science laboratory experiences for high school students, data emerging from the teacher interviews were first analyzed to detect themes present from the forty teachers as a whole. In determining whether any differences in these experiences occurred between districts serving differing racial, ethnic, and socioeconomic groups, the interviews were then separated into groups based on the three factors being investigated (district size, district socioeconomic groups served, and district diversity indicators). After groups were separated, the themes emerging from the initial analysis were revisited to detect any differences among groups.

Credibility of Analysis

Peer examination occurred at each stage of data analysis (Merriam, 1998). For all stages of qualitative analysis described, two researchers from the research project team worked together in analysis to achieve agreement on the emerging themes.

Questionnaire/Needs Assessment

After the Questionnaire/Needs Assessments were completed, the results were analyzed by the online survey instrument with the exception of the two open ended questions in the survey. The open-ended questions completed as part of the instrument were analyzed to identify emerging themes. As with the teacher interview analysis, peer examination occurred in the thematic analysis of the open-ended questions (Merriam, 1998).

Findings and Discussion

The research findings and discussion of the findings are presented for each research question.

Research Question 1: What are the experiences of high school students in science laboratories across the state?

The experiences of high school students were first revealed through the findings of the Classroom Observations using the Reformed Teaching Observation Protocol (RTOP) The RTOP findings are described as the extent to which students were engaged in classrooms, facilitated in a manner aligned with national standards documents. The RTOP instrument allows for scores from 0-100, with 0 not aligning to standards documents and 100 aligned to standards documents.

Table 2: Descriptive statistics for the entire sample:

	Mean	Median	SD	n	Max	Min
RTOP total score	53.46	54	17.21	40	88	20
LESSON DESIGN	8.53	7	3.92	40	17	3
PROPOSITIONAL	14.1	14	3.51	40	19	4
PROCEDURAL	8.45	7.5	4.12	40	18	2
COMMUNICATIVE	9.85	10	3.68	40	16	3
S/T RELATIONS	12.55	13.5	4.62	40	20	3

Table 3: Percentage of teachers within specific ranges of scores for the RTOP

Score Range	Number of Teachers in Range	Percentage of Teachers in Range
1 – 33 points	$n = 14$	35%
34 – 65 points	$n = 21$	52.5%
66 – 100 points	$n = 5$	12.5%

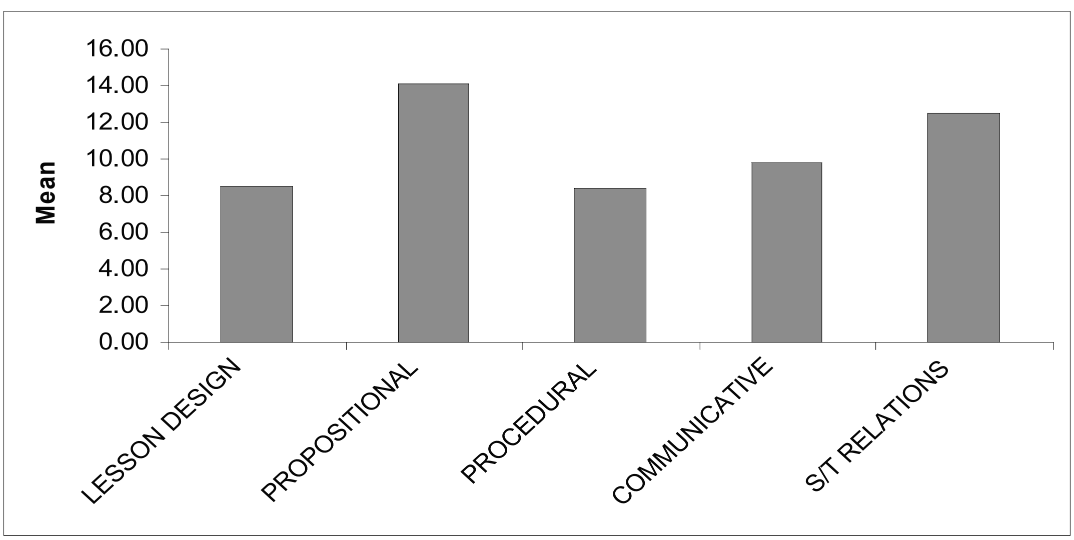
Table 2 reveals the descriptive statistics for the sample as a whole. This table is followed by information about the percentage of teachers' total score for the RTOP found for the different ranges of scores: between 1) 1-33, 2) 34-65, and 3) 66-100. (See Table 3.)

To learn more about the RTOP results found and the experiences of students in the classroom, the results were divided into the different subscales of the instrument to elucidate any differences which were occurring between the factors important in reformed teaching: 1) Lesson Design, 2) Propositional, 3) Procedural, 4) Communicative, and 5) S/T Relations. These subscale scores were then compared to reveal whether or not statistically significant differences between participants' scores on the subscales existed.

To complete this analysis, a one-way within-subjects (or repeated-measures) ANOVA was conducted to compare scores from the five RTOP subscales within the same teachers. Results indicated a significant overall effect, $F(4, 156) = 50.48$, $p < .0001$. Results of follow-up tests indicated that means from all pairs of subscales differed significantly from each other except for the comparison between Procedural and Lesson Design subscale scores. See Figure 1 below.

The classroom observations and teacher interviews collectively provided insight into the experiences of high school students in science laboratories across the state. The classroom observations revealed that students' experiences in science laboratories were somewhat aligned with reformed teaching as described by the standards documents (AAAS, 1989; NRC, 1996). This was evidenced in an average score approximately midway between

Figure 1: Average scores for each subscale of the RTOP (20 points possible)



reformed teaching and what might be considered more traditional facilitation. It is important to note that more teachers (35% with RTOP score between 1-33 compared to 12.5% with RTOP scores between 66-100) were observed facilitating instruction more aligned with traditional approaches to instruction. When parsing the RTOP average scores to compare classroom experiences in the areas measured by the different subscales, Figure 1 reveals a much higher average score for propositional knowledge when compared to other subscales associated with reformed teaching. The average scores for lesson design and procedural knowledge were approximately the same and the lowest of all subscales. When compared, a statistical difference was found between all subscales except lesson design and procedural knowledge.

These findings reveal a strong commitment and emphasis on propositional knowledge—one of two division of the RTOP Content subscale—that assessed "the quality of the content of the lesson" (Piburn et al., 2000, p. 8). When comparing the propositional knowledge to the other smaller division of the content subscale, procedural knowledge, this commitment and emphasis was diminished. This procedural knowledge division of the content subscale revealed the quality of "the process of inquiry" (Piburn et al., 2000, p. 8) experienced by students.

The Lesson Design subscale of the RTOP was designed to assess "the model for reformed teaching. It describes a lesson that begins with recognition of students' prior knowledge and preconceptions, that attempts to engage students as members of a learning community, that values a variety of solutions to problems, and that often takes its direction from ideas generated by students" (Piburn et al. , 2000, p. 8). This subscale was found diminished in comparison to the propositional knowledge subscale and approximately equal to the procedural knowledge division of the Content subscale. Teacher interviews revealed that most teachers used science laboratory experiences for more of what the NRC (2005) report describes as "secondary applications of concepts previously addressed by the teacher" (NRC, 2005, p. 25).

Typically the traditional laboratory experience is seen as a venue for illustrating, demonstrating, and verifying known concepts and laws.

The NRC (2005) report also revealed that laboratory experiences were rarely designed to integrate learning of the content of science with learning about the process of science. The findings from this study revealed little difference in this area throughout the state as was reflected in several teachers' response to the question: *Please explain how science content and process are emphasized in the science unit*, "I am not sure what you mean by emphasizing science process." When teachers did discuss process, the strategy most often employed involved the scientific method. An emphasis questioned in science education literature, due to a possible misrepresentation of the nature of science linked to the scientific method (McComas, 2004; Schwartz, Lederman , & Crawford, 2004).

The teacher interviews also revealed that high school students were not engaging in framing research questions, or commonly found designing experiments. The interviews did reveal that students are executing experiments, gathering and analyzing data, and constructing arguments, but these experiments were designed by the teacher. The questionnaire/needs assessment revealed findings similar to those emerging from both the classroom observations and the teacher interviews. Teacher interviews revealed little about students framing research questions or designing their own experiments. The results from the classroom observations whereby lesson design and procedural knowledge subscales were found to be lowest on average were consistent with the teacher interview findings. When teachers were asked in the questionnaire/needs assessment whether *students [in their classrooms] design procedures for testing their own predictions, estimations or hypothesis in science laboratory experiences,* seventy-four percent responded seldom or sometimes. While the report here by teachers may be a little more than what was revealed in classroom observations and in teacher interviews as far as the extent to which students are engaged in design, it is consistent in revealing that students do not engage in question framing and design to the extent suggested in standards documents aligned to reformed teaching and leading to attainment of science laboratory goals.

Research Question 2: What differences in science laboratory experiences, if any, are occurring between schools serving differing racial, ethnic, and socioeconomic groups?

Because the RTOP was used as a key indicator for revealing high school students' science laboratory experiences, comparisons of scores were used to investigate the extent to which differences were occurring between districts serving populations characterized by differing sizes, diversity characteristics, and socioeconomic status.

Three comparisons were made to determine whether or not statistically significant differences occurred between 1) classrooms observed in large districts compared to small districts, 2) districts serving students with low socioeconomic groups compared to districts serving students in higher socioeconomic groups, and 3) districts serving student populations with low diversity compared to districts serving student populations with high diversity. A series of independent-samples *t*-tests were conducted for each outcome variable from the RTOP.

Results of the comparisons indicated that there were 1) no significant differences between teachers from large and small school districts, 2) significant differences between teachers from districts serving students from high and low socioeconomic groups, and 3) no significant differences between teachers from districts serving student populations with high diversity versus low diversity student populations. Where significant differences were found between teachers from districts serving students from high and low socioeconomic groups significantly higher scores on the RTOP total score, and Propositional, Procedural, Communicative, and S/T Relations subscales were observed ($p < .05$) for the districts serving higher socioeconomic groups, while there was no significant difference between scores of teachers from districts serving students from high and low socioeconomic groups on the Lesson Design subscale.

While no differences where found when comparing districts with respect to size or diversity differences, findings revealing difference based on socioeconomic differences are cause for attention. Because evidence has been gathered to support a relationship between increased RTOP scores and student academic performance (Piburn et al., 2000, p. 24), there is need for additional attention to ensure that students from districts serving lower socioeconomic groups are not being underserved by their experiences in the science classroom.

Research Question 3: What are the perceived needs for improving science laboratory experiences for high school students?

Both the questionnaire/needs assessment and teacher interviews were used to reveal science teachers' perceived needs for improving science laboratory experiences for high school students. The discussion of these is organized according to the following categories: 1) Teacher Preparation for Laboratory Experiences, 2) Laboratory Facilities, Equipment, and Safety, and 3) Other influences and information about science laboratory experiences.

Teacher Preparation for Laboratory Experiences

Our research in this area was informed by both asking teachers the extent to which they felt comfortable regarding certain aspects of facilitating science laboratories and by responses offered by teachers when given an opportunity to share openly whatever they felt was important to facilitate science laboratory experiences. When asked directly, teachers, for the most part, revealed confidence in the level of preparation they received in science content (seventy-four percent prepared or very prepared), ability to lead students in science laboratory experiences where students are using laboratories tools and procedures, making observations, and gathering data (eighty-seven percent confident or very confident), and in assessing students in science laboratory experiences (eighty-three percent confident or very confident).

Research into teaching and learning as well as leading national science education organizations support a shift in science instruction away from laboratory experiences that illustrate, demonstrate, and verify known concepts and toward inquiry experiences.

While sixty-six percent of the teachers revealed that they felt prepared or very prepared because of the science process knowledge they received in their undergraduate education, thirty-six percent of the teachers expressed that they felt either unprepared or only somewhat prepared. Similar findings were revealed when teachers were asked to identify their confidence in leading students in science laboratory experiences where students pose the question, design and carry out the procedures to master science core content, and intended learning outcomes. Sixty-four percent expressed they felt confident or very confident, and thirty-four percent expressed that they felt unconfident or somewhat confident. These findings suggest that, while not all teachers revealed this, many teachers have some reservations about the extent to which they feel prepared to lead students in laboratories, to emphasize science process alongside science content. This was further revealed as teachers responded to the open-ended question, "*Is there any additional information you prefer to add regarding science laboratory experiences?*" Teachers expressed a concern for lack of pre-service and in-service training for facilitating inquiry laboratory experiences. This concern was also illuminated as some interviewed teachers revealed feeling unsure about what was meant by "science process," and the fact that most teachers relied predominantly on the scientific method as the mechanism for emphasizing science process in science laboratories. Teachers also revealed in interviews, that for the most part, students are not engaged in framing research questions or designing experiments. While other possible explanations might underlie teachers not engaging students in framing research questions and designing experiments, a lack of understanding of science process or belief in its importance, might be connected to teachers not prioritizing these activities for students. Instead, teachers were found focusing science laboratories more on what Hofstein and Lunetta (1982) described as traditional laboratory experience used as a venue for illustrating, demonstrating, and verifying known concepts and laws. This focus, found in this research, is not attuned to science process as much as it is directed toward science content. Teachers did however, on some levels, seem cognizant of the importance of inquiry laboratories as there were requests for help from the State Office of Education in identifying these types of laboratories that are connected to the Core Curriculum.

Laboratory Facilities, Equipment, and Safety

Eighty-two percent of the teachers responding to the questionnaire/needs assessment either taught in a science classroom, whereby the science laboratory facilities were integrated as part of the classroom, or had a separate laboratory classroom that they used. Nine percent of the teachers reported not teaching in a science classroom. Information about the facilities available to teachers was augmented by statements shared about whether they felt the laboratory facilities available inhibited or enhanced the laboratory experiences of their students. Forty-seven percent of the teachers reported feeling that their facilities enhanced or slightly enhanced students' experiences. Thirty-seven percent of teachers reported feeling their facilities either slightly inhibited or inhibited their students' experiences. A concern for facilities, equipment, and safety also emerged, as teachers described their administrative support of science laboratory experiences as insufficient in both funding for equipment and supplies. A concern for too many students and too little space which may lead to safety concerns, also emerged. These concerns were also found in a portion of the teachers interviewed who were offered an opportunity at the end of the interview to share additional information about science laboratory experience. One of the emerging themes coming from teachers was a lack of funding for science laboratory experiences. While class size was not a concern for all teachers, at least a quarter of those interviewed expressed concern, stating that they felt class size issues were resulting in increased safety risks for students, and issues with space for students to participate in science laboratory experiences. Additionally, sixty-five percent of the teachers responding to the needs assessment identified class size as the factor which reduces their ability to effectively supervise students engaged in these experiences.

Other influences and information about science laboratory experiences

This section reflects on teachers' beliefs about the influence of the Utah State Office of Education (USOE) on science laboratory experiences of students, as well as additional findings not addressed in other sections. When teachers were asked to describe the influence they felt the core curriculum had on the science laboratory experience offered to students, forty-eight percent of teachers reported feeling the core supported (supportive or very supportive) these experiences, with only twenty-percent who felt like the core was not supportive of lab experiences (very unsupportive or unsupportive). It is interesting to note that a large percentage (thirty-two percent) expressed a neutral opinion. This provides interesting information the USOE might use to reflect upon as the extent with which science laboratory experiences are valued, is reassessed. While USOE funding of this research signals a commitment to science laboratory experiences, this commitment may not be as evident to teachers across the state as is depicted in the large percentage of neutral responses.

When teachers were asked to express the extent to which the state accountability system is supportive of science laboratory experiences for students, only sixteen percent of teachers felt it was supportive (supportive or very supportive). Thirty-seven percent of teachers felt the state accountability system was not supportive (very unsupportive or unsupportive) of these experiences. Approximately half (forty-eight percent) of the teachers expressed a neutral opinion to this question. Teacher interviews revealed a small portion of teachers who believed that the large amount of content in the core inhibited the amount of time they felt could be devoted to laboratory experiences. These findings also support the need for continued reflection from the USOE as the commitment to laboratory experiences is considered alongside the message that is being conveyed by teachers through their perception of the extent to which accountability is aligned to this emphasis.

Teacher interviews revealed that a majority of did feel supported in offering laboratory experiences to students. When comparing factors connected to feelings of support to those connected to feelings of not being supported (offered by a smaller portion of teachers interviewed), administration believing in the value of laboratory experiences, making funding available for such experiences, ensuring that facilities are provided for science laboratories, and maintaining class sizes in which laboratory experiences are feasible, were factors that influenced these feelings.

Sixty-two percent of teachers felt the time allotted for preparation of science laboratory experiences during their regular workday was inadequate (inadequate or somewhat inadequate). This opinion also surfaced in the teacher interviews. Finally, minimal preparation time was expressed as a problem by teachers and should be considered as a possible factor related to the quality and amount of science laboratory experiences offered to students.

Discussion

Students' Experiences

The National Research Council's (2005) report, *America's Lab Report: Investigations in High School Science,* provided an assessment of the current state of science laboratory experiences for high school students across America. This research focused on the current state of science laboratory experiences for high school students across Utah. This current research revealed that student's science laboratory experiences were focused more on the learning of science content exclusively, neglecting learning about the process of science. This was evidenced through classroom observations when significantly higher scores for the propositional knowledge content subscale division were found when compared to the procedural knowledge division, and through teacher interviews that revealed confusion on behalf of some teachers when asked about process, or most teachers focusing solely on the scientific method as science process.

Hofstein and Lunetta (1982) noted that typically the traditional laboratory experience is seen as a venue for illustrating, demonstrating, and verifying known concepts and laws. The NRC (2005) recognized these same problems as traditional laboratory experiences were seen as "secondary applications of concepts previously addressed by the teacher" (NRC, 2005, p. 25). This same emphasis was found in this state with more than half of the teachers interviewed stating that they use labs to reinforce the ideas and concepts that the students are learning from bookwork, lectures, movies, and other learning activities. Research into teaching and learning as well as leading national science education organizations support a shift in science instruction away from laboratory experiences that illustrate, demonstrate, and verify known concepts and toward inquiry experiences (AAAS, 1993; Chang & Mao, 1999; Ertepinar & Geban, 1996; Hakkarainen, 2003; NRC, 1996; NRC, 2005; NSTA, 1998; Schwartz, Lederman , & Crawford, 2004,). Inquiry, as described in the National Science Education Standards allows students to "describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others" (NRC, 1996, p. 2). Students in Utah were not found engaging in science laboratories in a manner consistent with this definition of inquiry. Students were found carrying out experiments, collecting data, and drawing conclusions from their data, but they were not found asking questions or framing questions or designing experiments. The question emerging from this research is, "To what extent do students loose the established benefits of inquiry experiences when these experiences are truncated, distilled, or limited to carrying out laboratories that have been designed for them?" While inquiry instruction in the science classroom shows great promise for increasing students' understanding of science (Chang & Mao, 1999; Ertepinar & Geban, 1996; Hakkarainen, 2003), the nature of science (Schwartz, Lederman, & Crawford, 2004), and increasing students' interest and attitudes toward science (Cavallo & Laubach, 2001; Chang & Mao, 1999; Paris, Yambor, & Packard, 1998), it is uncertain to what extent this promise is realized when inquiry instruction is limited in the manner found most prevalent in the experiences observed in this state.

When the growing body of research available in cognitive research is examined as a lens for viewing the experiences of students within the state, additional insight can be gained. The NRC (1999) produced a report titled, *How People Learn,* that outlined specifically four principles that support effective learning environments. These four principles were: 1) learner-centered environments: environments that take into consideration the prior knowledge students bring to the classroom; 2) knowledge-centered environments: environments that help students learn with understanding through engaging with scientific ideas and in doing science; 3) assessment to support learning: assessment used to support learning through feedback by the use of formative assessment; and 4) community-centered environments: environments that are characterized by opportunities and motivation to interact and hear peers. In this research when considering learner-centered environments, the Lesson Design and Implementation subscale of the Reformed Teaching Observation Protocol used in making classroom observations emerged as subscale whereby facilitation was least aligned to reformed teaching. As knowledge-centered environments are considered, students were found to be consistently engaged in labs focused on scientific ideas and content. However, they were not normally found engaged in doing science, not to the extent that they asked their own questions and designed procedures to begin to answer those questions.

Finally, when considering the extent to which students in high school science laboratory experiences are offered opportunities and motivation to interact and hear peers, the findings from classroom observations across the state revealed that the communicative subscale of the RTOP were somewhat low and significantly lower than the propositional knowledge division of the content subscale, which identify the quality of the content emphasized. The communicative subscale of the RTOP assessed the classroom culture and focused on the extent to which students were involved in communicating their ideas to others and whether a significant amount of student communication occurred between and among groups of students. These findings related to science laboratory instruction, and its alignment to the four NRC (1999) principles, reveal opportunities for improvement focused on learner-centered environments, knowledge-centered environments, assessment to support learning, and community-centered environments.

Disparity in Experiences Afforded Students

Through the research completed in this project, variances of experiences students encountered across the state, on some levels, mirrored those found nationally. The NRC (2005) report indicated that racial, ethnic, and socioeconomic disparities exist when considering the amount of time different groups are afforded in the laboratory (NRC, 2005). While differences in the amount of time different groups were afforded in the laboratory did not emerge from this study, the findings did reveal disparities in the quality of the science laboratory experiences of students. Districts serving populations of students from lower socioeconomic groups were found to be receiving instruction significantly less aligned to reformed teaching when compared to districts serving populations of students from higher socioeconomic groups. This is cause for concern, continued attention, and effort in Utah as the state moves forward in continually improving science laboratory experiences.

Teacher Perceived Needs

The current research also sought to elucidate teachers' perceived needs for the continual improvement of science laboratory experiences for high school students. The findings suggest that while teachers did express confidence in their own science content preparation, they did not express this same confidence about their preparation in the science process. This left teachers unsure about the extent to which they would be able to integrate both the process and content of science into their instruction in ways that would support students and meet core standards. These findings, while disconcerting, do correspond with literature reporting that science teachers teach in ways that they were taught (Gieryn, 1999). Professional development literature investigating reform advocates moving away from an exclusive focus on science content, and toward teaching both content and process seamlessly. This type of professional development engages teachers as participants in science, especially in ways similar to that which they will be asked to employ in the context of your own classrooms (Lemke, 2001; Birman, Desimore, Porter,& Garet, 2000; Carlone and Webb, 2006; Stein, Smith, & Silver, 1999; NRC, 1999; NRC, 2001). Recommendations emerging from these findings in Utah are focused on these very principles to guide the state in supporting teachers and addressing these perceived needs.

Additional teacher perceived needs were also revealed related to facilities, equipment, safety, class size, administrative support, funding, preparation time, and the extent to which the Utah Core Curriculum and assessment systems supports science laboratory experiences. Each of these concerns, voiced by science teachers, prompted recommendations for supporting teachers so that less obstacles inhibit teachers' continued growth in the future as they seek to provide meaningful science laboratory experiences for high school students.

Conclusion

Through completing this research, Utah has taken an initial step toward improving science laboratory experiences. Recommendations have been put forth, based on these findings, to guide the state in supporting and collaborating with teachers. The data has been derived from classroom observations and information gleaned from teachers in the classroom. The *National Science Education Standards* suggest that in facilitating professional development for teachers, teachers should be the "source and facilitator of change" (NRC, 1996, p. 72). This research has provided a medium through which the teachers' voices were heard. Through appropriate planning and support advocated in the recommendations section of this research, this state has begun to set the stage for these changes in professional development to be met. This research is presented here with the intent of sharing the findings emerging in Utah's initial effort in the process of helping committed science teachers to continually improve laboratory experiences. It is hoped that these findings may also serve to focus and direct other states and nations in appraising and improving their own students' experiences.

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