# Chapter 5: Influential Factors on Student Perceptions of the High School Science Laboratory Environment

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Abstract

An expanding body of research has demonstrated the significant influence of the laboratory environment on student learning. Further research has demonstrated differences in student perceptions based on giftedness. To explore the relationship between giftedness and students' perceptions of their learning environment, we examined reported perceptions of laboratory learning environments. In addition, to explore the relationship between students' perceptions and the extent of their experience with laboratory learning in a particular discipline, we examined students' perceptions of their laboratory learning environments in first year biology courses versus elective biology courses. We found that students in high achieving courses had a more favorable perception of all aspects of their learning environments when compared to students in the regular courses. In addition, student perceptions of their lab appeared to be influenced by the extent of students' experience learning science. These findings have critical application in curriculum development as well as in the classroom.

## Introduction

Science laboratory learning has been lauded for decades for its role in fostering positive student attitudes about science and developing students' interests in science and ability to use equipment (Bates, 1978; Freedman, 1997; Hofstein & Lunetta, 1982; Thompson & Soyibo, 2002). Because the science laboratory offers opportunities for students to investigate scientific phenomena while working in small groups, the goals for laboratory learning extend beyond enhancing mastery of subject matter and technical or practical skills. Laboratory learning also aims to develop students' scientific reasoning skills, teamwork abilities, and understanding of the processes and nature of science, including the complexity and ambiguity of empirical work (NRC, 1996).

An expanding body of research has demonstrated the significant influence of the laboratory environment on student learning. Students' positive perceptions of their classroom environment and, in particular, of their science laboratory learning environment are linked with positive attitudinal and cognitive outcomes (B. J. Fraser, 1981; Rentoul & Fraser, 1979). Wong and Fraser (1997) investigated high school chemistry students' perceptions of their science laboratory environment in Singapore, determining that students' perceptions on all of the dimensions except for open-endedness were positively related to students' attitudinal outcomes. Fraser, McRobbie, and Giddings (1993) further determined that students' perceptions of their laboratory learning environment accounted for significant variance in their learning beyond that attributable to differences their abilities.

Given the potential for students' perceptions to enhance their attitudes about, interest in, and understanding of science, other student, teacher, and classroom qualities have been explored to determine their relationship with students' perceptions of their laboratory-learning environment. For example, correlational studies have identified significant differences in students' perceptions according to gender, age or grade level, and achievement (Dart et al., 1999; Kim, Fisher, & Fraser, 1999; Lang, Wong, & Fraser, 2005). Causal relationships have also been identified between instructional approaches, including those identified as constructivist or inquiry-based, and tighter alignment between students' perceptions of their actual and preferred laboratory learning environments (Hofstein, Nahum, & Shore, 2001; Kim, Fisher, & Fraser, 1999).

In addition, Lang and colleagues (2005) investigated the relationship between students' "giftedness" and their perceptions of their chemistry laboratory learning environment. Gifted students perceived their actual laboratory-learning environment more positively with respect to student cohesiveness, integration, and material environment. Yet, a number of factors in this study confound the interpretation that students' positive perceptions are attributable to their giftedness. First, the gifted stream students had smaller class sizes than the regular stream students. Second, the participating students were enrolled in chemistry classes and the observed differences may not be the same in classes in other disciplines. Chemistry laboratory environments are thought to differ from those in biology because of the nature and type of labs typically taught. For example, Hertz-Lazarowitz and colleagues (1984) found that biology laboratory activities more often engage students in work with their peers, while others have found that these activities are less often integrated into the flow of classroom learning when compared to chemistry courses (Schwab, 1963; Tamir & Friedler, 1994).

Hofstein, Cohen, and Lazarowitz (1996) found significant differences between students' perceptions of their actual chemistry and biology lab environments, specifically in the dimensions of integration, open-endedness, rule clarity, and organization (Hofstein, Cohen, & Lazarowitz, 1996). In this study, the biology and chemistry lab environments differed in the extent to which they engaged students in group work and investigation as well as more open-ended problem solving and discussion. These differences could be due to differences in the nature and types of laboratory experiences in these disciplines. Biology labs may more often include open-ended investigation, setting a tone that open-endedness is of value and offering more opportunities for students to become familiar and be successful in open-ended learning environments.

Finally, in studies examining correlations between students' perceptions of their learning environment and their achievement levels, few details are provided about the gifted versus regular laboratory learning environments, for example, whether the character of the environment differs with respect to instructional materials, pedagogy, or other aspects of the classroom context. To explore the relationship between giftedness and students' perceptions of their learning environment in other disciplinary contexts beyond chemistry, we examined students' perceptions of their laboratory learning environments in biology courses, including courses designated for high achieving versus regular achieving students. Because the students included in the sample were participating in two university-high school outreach programs, they were known to be experiencing some form of laboratory learning with access to a similar core set of materials. In addition, to explore the relationship between students' perceptions and the extent of their experience with laboratory learning in a particular discipline, we examined students' perceptions of their laboratory learning environments in first year biology courses versus elective biology courses that require first year biology as a pre-requisite.

## The Current Study and Learning Environment Research

High school biology students' perceptions of their science laboratory-learning environment were examined, including the influence of achievement and biology classroom experience, by addressing the following research questions: (1) Are there differences between "regular" and "high achieving" student perceptions? (2) Are there differences in perceptions of the environment among students in different grade levels? And (3) do the perceptions of students enrolled in first-year biology courses differ from those in courses beyond first-year biology?

Classroom type was used as proxy for achievement level. Specifically, students enrolled in advanced placement, international baccalaureate, honors, and special electives, as well as 1st year biology classes from specialized schools were considered "high achieving." Students enrolled in biology classes not otherwise characterized as advanced, honors, or elective were considered "regular achieving. First year biology classes were those that were in the first year of secondary school biology regardless of the type of school or achievement level of classroom. "Beyond" includes students enrolled in any class following the first year of biology, regardless of school and class.

These students' perceptions of their science laboratory learning environments were examined using the Science Laboratory Environment Inventory (SLEI). Initially developed by Fraser, McRobbie, and Giddings (1993), the measures of the SLEI examine students' perceptions of five aspects of their science laboratory learning environments: student cohesiveness, open-endedness, integration, material environment, and rule clarity. Student cohesiveness describes how well students know each other, work well together, and support one another. Open endedness refers to students' opportunities to design their own research and pursue individual interests to enhance their personal constructions of scientific knowledge. The Integration dimension characterizes how lab activities are connected to theoretical material taught in the lecture portion of the science class. Rule clarity is defined by how clearly the laboratory's structure and expectations are communicated and implemented. Material environment describes students' perceptions of the adequacy of their lab materials and equipment.

The authors of the SLEI conducted investigations of the psychometric properties of the instrument when it was initially developed (Fraser, McRobbie, & Giddings, 1993), but a comprehensive validation study was conducted in tandem with this study using Messick's unified definition of validity (Messick, 1989, 1995) through the application of confirmatory factor analysis and multi-dimensional Rasch analysis (Luketic, Wolfe, Singh, & Dolan, 2007). The dimensionality analysis revealed that a five-dimensional structure provided the best information and characterization. Removal of the 13 negatively worded items dramatically improved the reliability and validity of the measures of the model. Thus, the data described here are considered without the responses from negatively worded items.

## Methodology

### *Sample*

Students participating in two university-based pre-college outreach / partnership programs were selected purposively in order to ensure a high rate of response from students who were completing some form of laboratory learning. Schools were chosen to ensure that there were responses represented different grade levels, academic achievement levels, and biology classroom experience. Specifically, data were collected from public and private schools in three states (Virginia, Arizona, Missouri) that had been involved in one to four yearlong partnerships with a research university in a mid-Atlantic state. Surveys were distributed to 900 students in 17 schools; 355 students from 11 schools completed responses.

In the responding classrooms, student to teacher ratios ranged from 12.4 to 20.5 students per teacher. School sizes ranged from 300 to 4,000 students, and school settings included rural, urban fringe (small, medium and large city), and small and large towns. The proportions of students receiving free or reduced lunch at each school ranged from 3% to 40%, and the ethnic or racial minority population of the schools ranged from 10% to 40% (NCES, 2007).The sample of 355 students were 35% male (n=123) and 65% female (n=226). In addition, 68% (n=236) of the participants were European American while 32% (n=107) were a racial or ethnic minority. The majority of students were enrolled in a variety of biology courses.

*Procedures*

Students' perceptions of their classrooms' science laboratory environment were collected using a paper version of the Science Laboratory Environment Inventory (SLEI) during the 2006-2007 school year. Students completed the questionnaire during class-time. The SLEI contains thirty-five items (Fraser, McRobbie, & Giddings, 1993), measuring five dimensions comprising seven questions each. Responses were recorded on a 5-point Likert-type scale (1= almost never, 2= seldom, 3=sometimes, 4=often, 5= very often). Information about demographic indicators (i.e., grade in school, course of study, gender, and ethnicity) was collected using a one-page attachment to the SLEI.

Based on findings from a complementary study (Luketic et al., 2008) the negative items were removed from the data set for purposes of the analysis (Marsh, 1996). These reverse worded items did not measure the dimensions in the same way the other items were working. Instead, they acted as an additional factor in the composition of the science classroom environment construct. The remaining 22 items were used to explore the research questions presented here.

*Analyses of measure estimates*

Differences in predicted response rates based on grade and course type and science program type were investigated through analysis of the means and standard deviations of the Rasch measures for individuals and groups from the “Actual” form of the SLEI. Expected response rates across these subgroups were reviewed to determine if there were any meaningful differences. Rasch difficulty estimates were completed to compare responses across sub-groupings.

The grade variable was divided into the four high school grade levels: $9^{th}$, $10^{th}$, $11^{th}$, and $12^{th}$. We expected to see differences in the estimates for these dimensions with higher positive estimates for the older, more advanced grades. One-way analysis of variance was completed for each of these variables for each of the five dimensions identified in the measures of this instrument. This analysis was completed to examine the Rasch measure estimates for significant differences.

The data were further analyzed for differences in perceptions based on achievement level, biology learning experience by grade level (i.e., $9^{th}$, $10^{th}$, $11^{th}$, and $12^{th}$), and experience by years of biology coursework completed (i.e. $1^{st}$ year, and beyond). Multivariate analysis using the least squares procedure was completed using JMP software (JMP 2006). This modeling examined student perceptions based on grade and achievement level as well as the interaction of grade level, achievement, and years of biology course experience on the expected response rates.

## Results

Students in high achieving courses had a more favorable perception of all aspects of their learning environments when compared to students in the regular courses (Figure 1). The differences between regular and high achieving students were statistically significant, although the effect sizes were small. The most significant differences were found between Student Cohesiveness ($F(1,351) = 26.86$, $p < .0001$, $\eta^2 = 0.071$); Integration ($F(1,351) = 25.00$, $p < .0001$, $\eta^2 = 0.066$); and Rule Clarity ($F(1,351) = 11.29$, $p = .0009$, $\eta^2 = 0.031$). The small effect sizes indicate that while there are significant differences, there are likely a number of other factors influencing student perceptions.

To explore how student perceptions of their lab may be influenced by the extent of students' experience learning science, two variables were examined as proxies for experience: grade level and experience in biology coursework per se (Figure 2). With respect to grade level, 9th graders were considered to have the least experience and $12^{th}$ graders the most. Grade level differences in student perceptions were statistically significant ($p < .001$) across all five factors of the lab environment. Our analysis showed that $9^{th}$ graders tended to be more negative than students in other grades. Tenth graders reported the most positive perspective of all the students. Eleventh graders were more positive than $12^{th}$ graders. Effect sizes range from 0.039 to 0.074.

The negative perceptions of ninth graders may have been attributable to their lack of experience in biology coursework per se, as the nature of biology laboratory learning differs from such learning in other disciplines (Hertz-Lazarowitz et al., 1984). To explore this further, first year biology students were compared to those beyond their initial biology class experience (Figure 3). Biology classroom experience influenced student perceptions between first student and those beyond the first year. Negative perceptions of the classroom environment were reported for first year students. In contrast, students beyond the first year were found to have positive lab environment perspectives. The notable exception to this trend is in the Open Endedness dimension where there was no statistically significant difference between the first year and all other students (mean =0.04 & -0.02, s.d.=0.40). The most meaningful differences between the students in first year and all other classes were instead found in the dimensions Student Cohesiveness ($F(1, 351)= 5.78$, $p=.0008$, $\eta^2=0.02$); Integration ($F(1, 351)=8.34$, $p= .0041$, $\eta^2=0.004$); and Material Environment ($F(1, 351)= 7.58$, $p=.0062$, $\eta^2=0.021$).

In our sample, students' grade levels correlated with their achievement and biology course experience. To determine whether grade level, achievement level, or biology course experience was the primary influence on students' perceptions, we examined whether students in the same grade level perceived their environment the same regardless of achievement or experience level. Similarly, we investigated whether students in the same achievement or experience level were similar in their perceptions of the laboratory regardless of grade in school. These analyses revealed that differences in perception were consistent across academic achievement groups as well as experience level by first year and beyond (course level) rather than by grade level (Table 1). Perceptions were consistent among regular and high achieving students regardless of grade level. In addition, first year and beyond student perceptions were consistent regardless of grade level.

## Discussion

In this study, students enrolled in high achieving biology courses reported more positive perceptions of all aspects of their laboratory-learning environment, with the exception of their material environment. This finding suggests that the positive perceptions of material environment reported by gifted stream students (Lang et al., 2005) may be attributable to other factors, such as access to different laboratory materials or class size In addition, the students in this study reported more positive perceptions of open-endedness, which was not observed in Lang and colleagues' investigation of high school chemistry students' perceptions (2005).

Examining student perceptions by experience level revealed that students earlier in their biology learning (i.e., first year biology students) were predominantly negative in their perceptions, while students beyond their first year of biology reported more positive perspectives. Students enrolled additional biology courses (i.e., beyond first year) may have additional practice grappling with open-ended problems and working in groups (Hertz-Lazarowitz et al., 1984). As a result, students who take additional biology courses may become more comfortable with open-ended group work and thus more positive about student cohesiveness and open-endedness. More generally, students with less experience in high school science courses (i.e., $9^{th}$ grade students) were also more negative about their laboratory learning environments. Less experienced students, including those less experienced in school (i.e., $9^{th}$ grade students) and in biology coursework (i.e., first year students) may require more structure and guided interaction with their peers. Similarly, less experienced students may benefit from additional opportunities to practice open-ended and group work with appropriate support and explanation.

Student's positive perceptions seemed to peak in $10^{th}$ grade. If this finding holds true across a larger sample, then $10^{th}$ grade science classrooms may present good venues for capitalizing on the positive trend in students' perceptions. For example, $10^{th}$ grade may be a good time to offer more open-ended laboratory activities and encourage group work in lab. Finally, special efforts could be made to maintain the positive perceptions of students as they transition from $10^{th}$ to $11^{th}$ and $12^{th}$ grades.

Figures

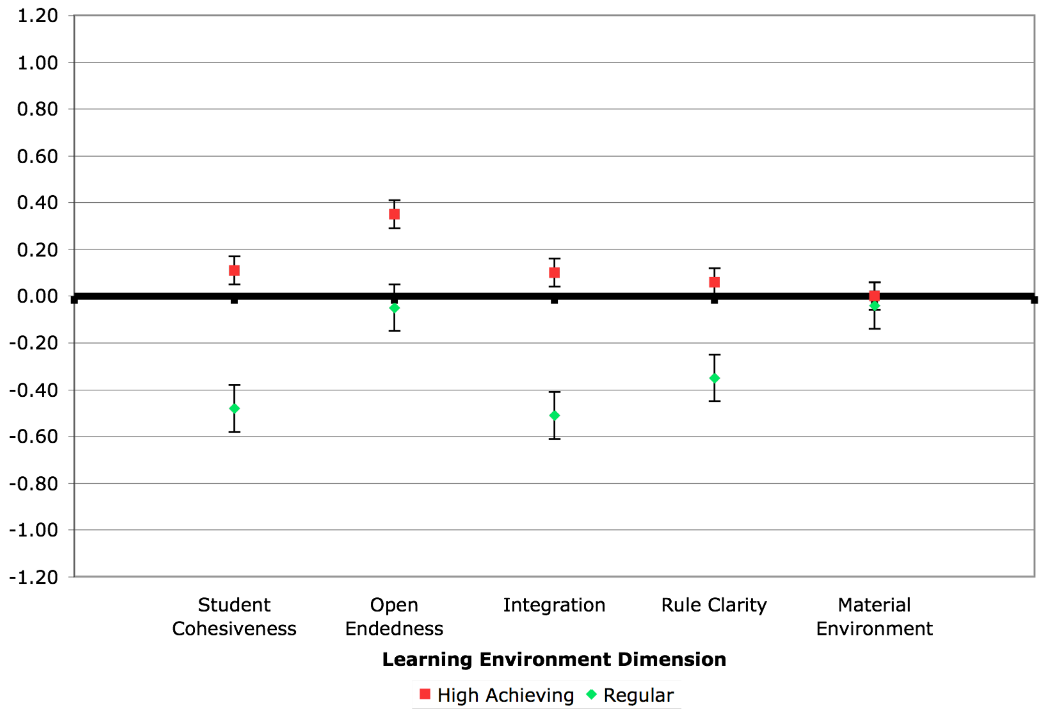


*Figure 4 (Figure 1) Differences in student perceptions across the five measures between regular and high achieving classrooms*

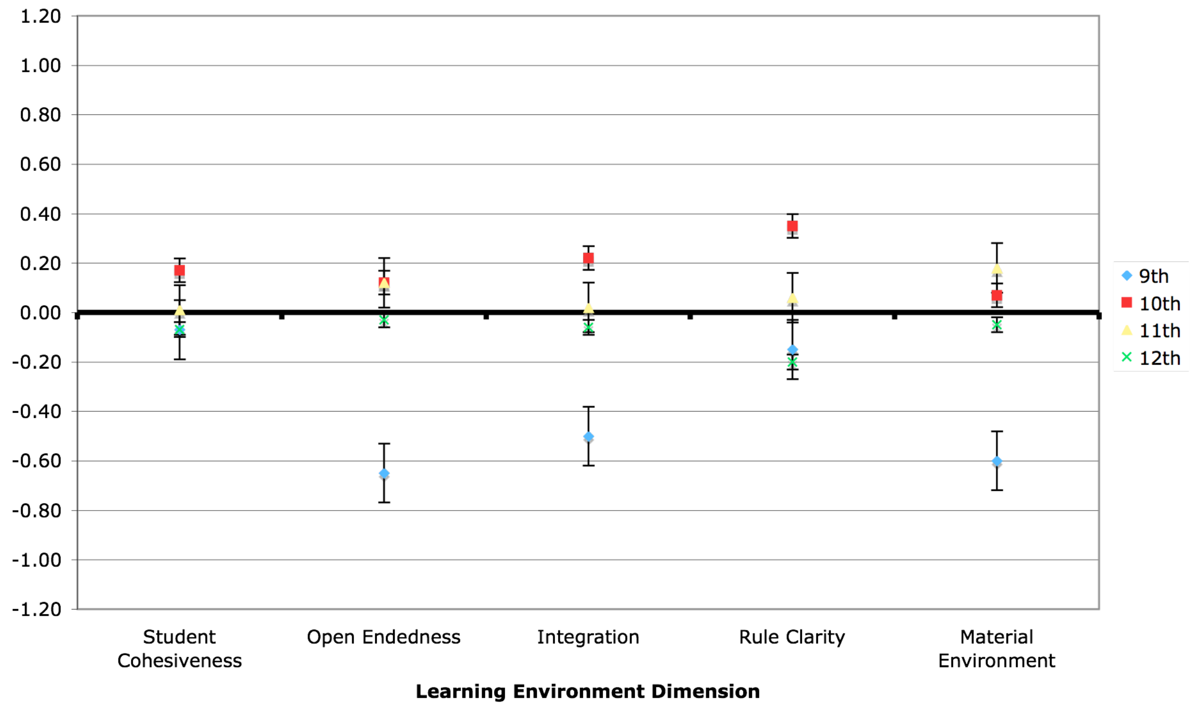


*Figure 5 (figure 2) Differences amongst student perceptions across the five measures by grade level*

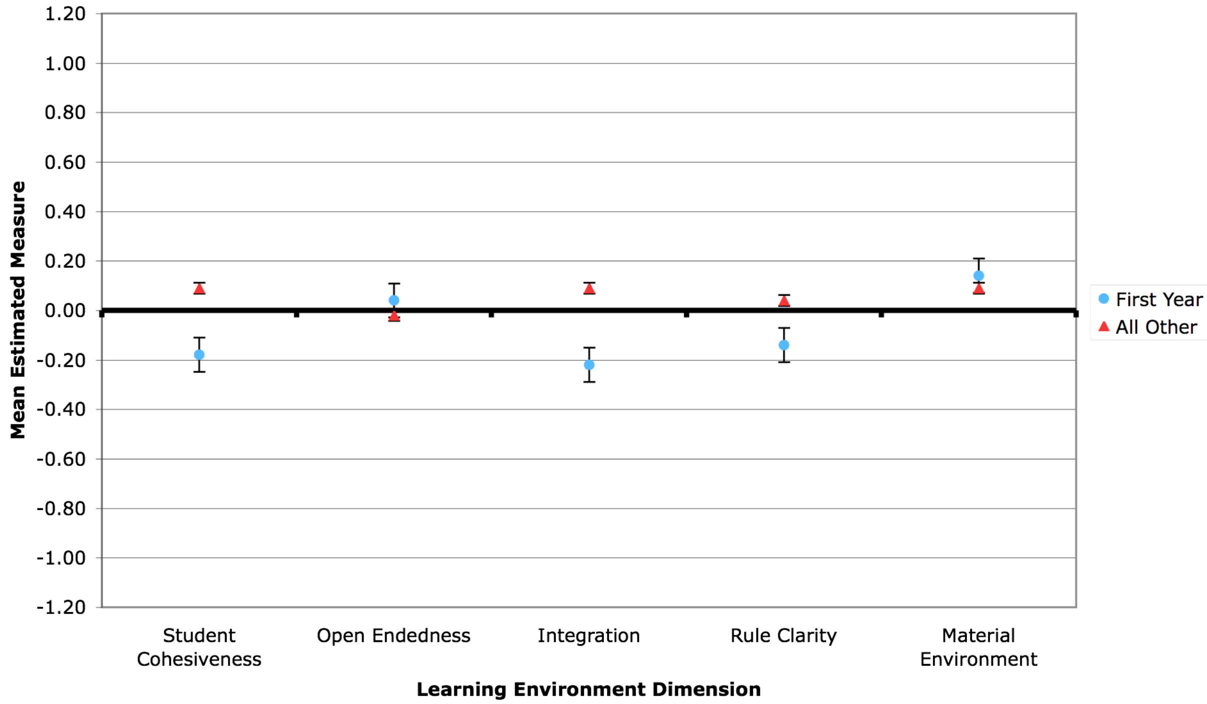


*Figure 6 (Figure 3) Differences between the first year classroom and beyond of the lab environment between 10$^{th}$ and 11$^{th}$ grade students and biology experience and achievement level*

Table 14 (Table 1)

*Differences in perceptions by dimension, grade, and achievement and experience*

| | Achievement: | | Experience: | | Overall |
|---|---|---|---|---|---|
| | Regular | High | 1st year | Beyond | |
| Student Cohesiveness | | | | | |
| 10th grade | -0.35 | 0.42 | 0.03 | 0.43 | 0.17 |
| 11th grade | -0.12 | 0.19 | -0.02 | 0.25 | 0.01 |
| Total | -0.48 | 0.11 | -0.18 | 0.09 | |
| Open Endedness | | | | | |
| 10th grade | 0.00 | 0.33 | 0.19 | 0.07 | 0.12 |
| 11th grade | -0.14 | 0.02 | 0.08 | 0.05 | 0.12 |
| Total | -0.05 | 0.01 | 0.04 | 0.02 | |
| Integration | | | | | |
| 10th grade | -0.34 | 0.50 | 0.07 | 0.59 | 0.22 |
| 11th grade | -0.17 | 0.11 | 0.20 | 0.20 | 0.02 |
| Total | -0.51 | 0.10 | -0.22 | 0.09 | |
| Rule Clarity | | | | | |
| 10th grade | -0.17 | 0.56 | 0.20 | 0.58 | 0.35 |

| | Achievement: | | Experience: | | Overall |
|---|---|---|---|---|---|
| | Regular | High | 1st year | Beyond | |
| 11th grade | -0.12 | 0.01 | 0.33 | 0.11 | 0.06 |
| Total | -0.35 | 0.06 | -0.14 | 0.04 | |
| Material Environment | | | | | |
| 10th grade | 0.13 | 0.57 | 0.37 | 0.35 | 0.07 |
| 11th grade | -1.04 | 0.06 | 0.04 | 0.05 | 0.18 |
| Total | -0.04 | 0.00 | 0.14 | 0.09 | |

Table 15 (Table 2)

*Statistical significance and effect size by academic grouping within grade*

| | F (1,351) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Statistical Significance | | | | Effect Size (where relevant) | | | |
| Dimension | Regular | High Achieving | First Year | Other | Regular | High Achieving | First Year | Other |
| Student Cohesiveness | 0.77 | 4.24* | 6.34* | 2.85 | 0.00 | 0.03 | 0.10 | 0.03 |
| Open Endedness | 0.41 | 16.37** | 7.75** | 2.53 | 0.00 | 0.11 | 0.12 | 0.02 |
| Integration | 0.98 | 4.15* | 6.63* | 2.11 | 0.00 | 0.03 | 0.10 | 0.02 |
| Rule Clarity | 1.16 | 5.72** | 7.04** | 1.55 | 0.00 | 0.04 | 0.11 | 0.01 |
| Material Environment | 1.99 | 17.14** | 6.21* | 4.04* | 0.00 | 0.11 | 0.10 | 0.02 |

* $p < .05$, ** $p < .001$

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