Exploration of Relationships between Students’ Science Identities and Achievement Emotions in Physics

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Abstract: Many studies have found relationships between students’ achievement emotions and their performance as well as between students’ science identities and their performance. However, little is known about how students’ achievement emotions are related to their science identities. This study explored the relationship between achievement emotions and science identities in an inquiry-based physics class. In order to do so, we adapted the Achievement Emotions Questionnaire-Mathematics by replacing all references to mathematics with physics and selected items from the Persistence Research in Science and Engineering (PRiSE) survey. The adapted instruments were implemented with students in an inquiry-based physics class. The results showed that, overall, students’ self-perceptions as science persons were low, especially as chemistry or physics persons. Students also had negative emotions overall about physics. The results showed that students’ anxiety levels were significantly increased in a test-related situation compared to class-related and learning-related situations. In terms of the relationships between their science identity and their achievement emotions, students’ self-identification and their perceptions about their parents/relatives/friends’ views about them as physics persons were significantly related to their achievement emotions in physics. We also found that tests triggered great anxiety for students regardless of their pride in and enjoyment of physics.

Keywords: achievement emotion; science identity; physics

1. Introduction

Attention to students’ emotions related to their learning has increased and already been shown to be an essential aspect of students’ learning [1]. Students may enjoy their classes and homework and be proud of their achievements. They may also be angry with their classes, feel shame about their achievement, be bored with their homework, and feel hopelessness about their tests. As such, Pekrun et al. [2] found that students’ emotions were linked to their learning and achievement. Emotions have been inconsistently defined throughout research literature [3]. Nonetheless, emotions are commonly viewed as affective responses to particular stimuli that are quick and automatic [4] and are characterized by situation-specific appraisal functions [5]. Emotions are known to influence a student’s academic performance [1]. Specifically, students’ emotions in relation to their academic activities (e.g., studying, taking exams, attending class) and outcomes (e.g., the success and failure outcomes of their academic activities) are called achievement emotions [6]. Achievement emotions can be distinguished by two types of emotions: activity emotions related to achievement activities and outcome emotions related to outcomes from these activities [6]. In outcome emotions, an important distinction exists between prospective outcome emotions related to anticipated future success and failure and retrospective outcome emotions related to past success and failure. Examples of prospective outcome emotions are anticipatory joy and hopelessness about future outcomes. By contrast, retrospective outcome emotions are the product of past events and follow appraisals of success and failure such as pride, shame, and relief [6].
In studies related to achievement emotions, control-value theory [6] has been widely used and accepted to understand the influence of emotions on students’ learning and achievements [7,8]. Control-value theory explains that emotions have valence (positive/negative) and activation (activating/deactivating). In terms of valence, positive states such as enjoyment and pride are distinguished from negative states such as anger and anxiety. As for activation, “physiologically activating states can be distinguished from deactivating states, such as activating excitement versus deactivating relaxation” [9] (p. 261). Pekrun et al. [10] selected nine different achievement emotions (enjoyment, hope, pride, relief, anger, anxiety, hopelessness, shame, and boredom) that occur often in students and represent major emotions categories from theory-based emotion taxonomies. They also categorized those emotions according to control-value theory; for example, positive activating emotions are enjoyment, hope, and pride; a positive deactivating emotion is relief; negative activating emotions are anger, anxiety, and shame; and negative deactivating emotions are hopelessness and boredom.

Individuals naturally judge their ability in relation to their performance of tasks. This self-concept about ability has positive effects on students’ enjoyment and pride, and negative effects on their anger, anxiety, shame, and hopelessness [11]. Pekrun [6] proposed the importance of self-concept of ability for students’ achievement emotions and found solid evidence to support the idea of self-concept acts as a mediator in the relationship between achievement and emotion. Students’ earlier performance has an influence on their self-concept, and their prior self-concept significantly affects their future performance [12]. Hazari et al. [13] also claimed that students’ performance directly affects their identity in a disciplinary field such as physics, and their identity also has an effect on their career choice and their future performance. In other words, how students identify themselves in science-related fields is associated with their academic success and future career choices. Student identity as a science person (i.e., scientist) has drawn attention from science education researchers as an attribute critical to students’ success. For example, having a science identity plays an important role in student involvement [14], persistence in science majors [15], and selection of science-related careers [16,17]. Nonetheless, a traditional school physics curriculum focuses on cultivating short-term knowledge and interest in science, which promotes a narrow science identity that does not appeal to a broad range of students [16]. The science identity model conceived by Carlone and Johnson [16] contains “science performance”, “competence”, and “recognition” as interrelated constructs. Later, Hazari et al. [13] expanded the model by including “interest” in science as a fourth construct. However, in the components of science identity, students’ emotions have not been included.

In summary, many studies have found relationships between achievement emotions and performance and between science identity and performance. However, the relationship between achievement emotions and science identity has not been investigated, at least not at the time that this study was conducted. In addition, an emphasis on the importance of science inquiry in science classrooms has been widely accepted as a critical factor for student engagement and understanding of science concepts [18,19]. There is an overwhelming number of studies on the effectiveness of inquiry-based science teaching and learning. Recently, the role of affect has been discussed in many studies as part of learning science but also as a way to engage students in scientific inquiry [19–21]. However, little is known about how students’ achievement emotions are related to their science identities in an inquiry-based science class. This study aimed to fill the gap in the current literature by exploring the relationship between achievement emotions and science identities in an inquiry-based physics class. Our guiding research questions are as follows:

- How do college students in an inquiry-based physics class self-identify as biology, chemistry, and physics persons? How do those students perceive their parents’/relatives’/friends’ and their teacher’s/professor’s views on them as biology, chemistry, and physics persons?
- What patterns are found in students’ achievement emotions in an inquiry-based physics class?
• What are the relationships between achievement emotions and science identities in college students?

2. Materials and Methods

2.1. Questionnaire

In order to investigate students’ achievement emotions and science identities, we based our questionnaire on two instruments, the Achievement Emotions Questionnaire-Mathematics (AEQ-M) \[22\] and the PRiSE survey \[13\]. AEQ-M is a self-report instrument measuring students’ achievement emotions experienced in mathematics \[22\]. It contains 60 items measuring seven discrete emotions (enjoyment, pride, anger, anxiety, shame, hopelessness, and boredom); and items were developed to address three pedagogical situations: mathematics class-related, learning-related, and test-related experiences. Thus, AEQ-M consists of three sections of items (class-related, learning-related, and test-related). Here are some example items of AEQ-M \[22\]: class-related item—“I look forward to my math class”; learning-related item—“Just thinking of my math homework assignments makes me feel bored”; and test-related item—“I am so anxious that I would rather not take the math test”. Within each section, items are ordered in three temporal situations: before, during, and after. In other words, in the questionnaire, Pekrun et al. indicated which situations students should consider when they rate their feeling. For example, they inserted “The following questions pertain to feelings you may experience BEFORE attending math classes” in the questionnaire before students responded to items addressing the “Before” situation. Similarly, they included sentences throughout the questionnaire to guide students as to which situation (before, during, or after) they needed to consider when they respond items. For the full version of AEQ-M, please see Pekrun et al. \[22\]. Since AEQ-M was designed for a mathematical disciplinary context, we adapted AEQ-M by replacing all references to mathematics with physics. We named the adapted instrument “AEQ-P”, with P indicating “physics.” For each item, we asked the participant students to give a response on a 5-point Likert scale from 1 (“strongly disagree”) to 5 (“strongly agree”).

Next, we selected items from the Persistence Research in Science and Engineering (PRiSE) survey to investigate students’ physics identity. The PRiSE survey was designed to identify factors that influence student persistence in STEM disciplines and contained 50 items \[13\]. For instance, items asked students’ demographic information, career plans, middle school science experiences, high school backgrounds and science courses experience, and attitudes and interests in science. As such, most items were designed to see relationships between students’ identity as science persons and other factors such as their career plans, prior experiences, and attitudes. Thus, in this study, we selected questions asking directly how they or others see themselves as science persons. Those selected items were: (1) Do you see yourself as a biology/chemistry/physics person? (2) Do your parents/relatives/friends see you as a biology/chemistry/physics person? and (3) Does your science teacher/professor see you as a biology/chemistry/physics person? These items were rated on an anchored scale of 1 (No, not at all) to 6 (Yes, very much). The two adapted instruments were combined and administered online to students in an inquiry-based physics class.

2.2. Participants and Context

Participant students were college students who were taking an inquiry-based introductory physics course in a large research university in the U.S. The physics course was inquiry-based and did not offer a lecture throughout the entire semester. According to the course instructor, the instructor and his/her colleague designed a workbook following the format of Physics by Inquiry \[23,24\]. The course did not assign a textbook, so students were supposed to follow instructions in the workbook and complete tasks as a group. The course syllabus indicated that the course learning objective was for students to be able to demonstrate problem-solving and critical thinking skills consistent with experiments, such as the development and use of models. Since this class was inquiry-based, science
experiments and hands on activities were required for students to perform for almost every lesson. Thus, the class size was smaller than a typical lecture-based physics class. When this study was conducted, 47 students were enrolled in the course, and 25 students responded voluntarily to the questionnaire. This course was open to all majors, meaning that both physics and non-physics students could enroll. We did not include an item asking their majors to comply with our approved IRB proposal. However, given that only two participant students were freshmen, we could say that most of participants had already taken other introductory level science courses, such as biology or chemistry, as their university required them to take until they had finished their undergraduate programs. We administered the questionnaire in the middle of the physics course. Note that the researchers did not get involved in teaching the course or designing the course materials or activities. The questionnaire included optional demographic questions, to which all participants responded voluntarily. Those optional questions asked the student’s gender, year in college, and ethnicity. Table 1 presents the information that the participants gave for those optional questions.

Table 1. Participant Students’ Demographic Information.

| Gender  | Year in College | Ethnicity         |
|---------|-----------------|-------------------|
| Female: 19 | Freshman: 2    | White: 17         |
| Male: 6 | Sophomore: 7    | Latinx or Hispanic: 5 |
|         | Junior: 11      | Asian: 1          |
|         | Senior: 5       | Two or More: 2    |

2.3. Analysis

Data was analyzed using descriptive statistics, nonparametric statistics (the Wilcoxon matched paired test), and correlation statistics between variables. For example, data was analyzed using correlation statistics to see relationships between students’ science identities and their achievement emotions in physics. Moreover, data was analyzed to see relationships among those achievement emotions in physics in three pedagogical situations: class-related, learning-related, and test-related. A Wilcoxon matched paired test was used to compare students’ anxiety levels between different pedagogical situations. IBM SPSS Statistics 27 was used to conduct those analyses. Due to the small number of participants (less than 30), we did not conduct inferential statistics (e.g., ANOVA) to compare different groups of students, e.g., by gender, years in college, or ethnicity. Instead, we focused on a specific group of students who were engaged in an inquiry-based physics course.

3. Results

3.1. Science Identity

Items asked students if their parents/relatives/friends or their science teacher/professor saw them as biology/chemistry/physics persons, or if they saw themselves as such. Those items were rigorously validated and found reliable in Hazari et al.’s [13] study. Hazari et al. [13] established face and content validity for the survey with science education experts and students, meaning that they provided evidence to support the individual item’s content and face validity. In their study, a reliability coefficient (Cronbach’s alpha) was 0.83. In our study, a reliability coefficient using the selected items was 0.89. Figure 1 shows student response frequencies for the science identity items asking their perceived self-identification. The items were scaled from 1 to 6, with scale 1 being the lowest level of self-identification and scale 6 being the highest level of self-identification. When responses of scales 1, 2, and 3 were classified as a “low” level of self-identification, and responses of scales 4, 5, and 6 were classified as a “high” level of self-identification, the result illustrated that students tended to identify themselves as chemistry or physics persons at a low level (15 responses for chemistry and 18 responses for physics at the low level). In terms of self-identification as a biology person, we found that the same number of students responded at the low (n = 12) and high (n = 12) levels.
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Figures 2 and 3 present response frequencies for items asking about students’ perceptions of their parents'/relatives'/friends' or their science teacher's/professor's views of them as biology/chemistry/physics persons. The distributions were similar to those in Figure 1, indicating that students perceived that their parents/relatives/friends or their science teacher/professor saw them as chemistry or physics persons at a low level. In terms of being viewed as a biology person, two students responded with scale 6 to the item asking their parents'/relatives'/friends' views (see Figure 2) and three students responded with scale 6 to the item asking their teacher's/professor's view (see Figure 3). In Figure 1, six students responded with scale 6. This finding implies that students were less confident in rating how others viewed them as a biology person compared to their self-identification as a biology person. However, when comparing the low level (scales 1–3) and the high level (scales 4–6) of identifications, only one response was shifted to the low level compared to the results seen in Figure 1. Specifically, the number of students who rated at the low level was 13 in both cases (Figures 2 and 3) and the number of students who rated at the high level was 11. After checking students’ individual responses to each item, we found that one student who rated at the high level for the self-identification as a biology person question (Figure 1) rated at the low level for the other two items.

**Figure 1.** Student response frequencies for science identity items.

**Figure 2.** Frequencies for parents'/relatives'/friends' perception about students' science identity.

**Figure 3.** Frequencies for science teacher's/professor's perception about students' science identity.
3.2. Achievement Emotion in Physics

Table 2 presents the descriptive statistics results for each emotion measured by the AEQ-P. Reliability coefficients, Cronbach’s alpha, were all above 0.80, indicating that the sets of items for each emotion demonstrated good internal consistency. Skewness results showed that the distributions of enjoyment, pride, anger, and boredom were moderately and negatively skewed (the skewness is between $-1.0$ and $-0.5$), the distribution of shame was fairly symmetrical (the skewness is between $-0.5$ to $0.5$), and the distributions of anxiety and hopelessness were highly and negatively skewed (less than $-1.0$). Those findings indicated that participant students seemed to be moderately enjoying and feeling proud of their achievement in physics, while they also had high anxiety and hopeless feelings about physics.

Table 2. Descriptive Statistics for Scales of the AEQ-P.

| Emotion    | No. of Items | Possible Range | M     | SD  | Skewness | α   |
|------------|--------------|----------------|-------|-----|----------|-----|
| Enjoyment  | 10           | 10–50          | 22.40 | 8.94| $-0.922$ | 0.85|
| Pride      | 6            | 6–30           | 15.44 | 6.70| $-0.694$ | 0.85|
| Anger      | 9            | 9–45           | 26.12 | 11.83| $-0.556$ | 0.94|
| Anxiety    | 15           | 15–75          | 49.92 | 19.33| $-1.357$ | 0.95|
| Shame      | 8            | 8–40           | 21.52 | 9.73| $-0.457$ | 0.89|
| Hopelessness| 6            | 6–30           | 19.80 | 8.18| $-1.034$ | 0.90|
| Boredom    | 6            | 6–30           | 12.76 | 5.49| $-0.770$ | 0.83|

As previously described, the questionnaire was designed to address three pedagogical situations: class-related, learning-related, and test-related. Table 3 presents descriptive statistics computed for each emotion in those three situations. Noticeably, in the test-related situation the emotion of pride was lower than in the other two situations, and the anxiety and hopelessness feelings were high and highly negatively skewed. The findings imply that the test-related situation provided a context that induced strong negative emotions and a weak positive emotion.
Table 3. Descriptive Statistics for the Scales in Three Pedagogical Situations.

| Emotion         | No. of Items | Possible Range | M     | SD   | Skewness |
|-----------------|--------------|----------------|-------|------|----------|
| **Class-related emotions** |              |                |       |      |          |
| Enjoyment       | 4            | 4–20           | 9.56  | 4.18 | −0.698   |
| Pride           | 2            | 2–10           | 5.64  | 2.71 | −0.585   |
| Anger           | 4            | 4–20           | 11.04 | 5.70 | −0.198   |
| Anxiety         | 4            | 4–20           | 11.72 | 4.93 | −0.791   |
| Shame           | 2            | 2–10           | 5.08  | 2.69 | −0.106   |
| Boredom         | 3            | 3–15           | 6.08  | 2.63 | −0.738   |
| **Learning-related emotions** |              |                |       |      |          |
| Enjoyment       | 3            | 3–15           | 6.04  | 2.88 | −0.328   |
| Pride           | 2            | 2–10           | 5.88  | 2.37 | −1.297   |
| Anger           | 3            | 3–15           | 9.16  | 4.15 | −0.655   |
| Anxiety         | 4            | 4–20           | 12.52 | 5.30 | −0.925   |
| Shame           | 3            | 3–15           | 7.24  | 3.56 | −0.010   |
| Boredom         | 3            | 3–15           | 6.68  | 3.05 | −0.607   |
| **Test-related emotions** |              |                |       |      |          |
| Enjoyment       | 3            | 3–15           | 6.80  | 2.57 | −1.239   |
| Pride           | 2            | 2–10           | 3.92  | 2.33 | 0.580    |
| Anger           | 2            | 2–10           | 5.92  | 2.48 | −0.789   |
| Anxiety         | 7            | 7–35           | 25.68 | 9.53 | −1.649   |
| Shame           | 3            | 3–15           | 9.20  | 4.32 | −0.462   |
| Hopelessness    | 6            | 5–30           | 19.80 | 8.18 | −1.034   |

Items addressing the hopelessness emotion were included only in the test-related situation, meaning that anxiety could be the focus of analysis for comparing students’ anxiety emotion across the three pedagogical situations. In order to do so, we conducted a Wilcoxon matched paired (nonparametric) test. The analysis results showed that there was a statistically significant increase in anxiety in the test-related situation compared to the learning-related situation (z = −4.206, p < 0.001) and to the class-related situation (z = −4.210, p < 0.001), whereas there was no significant difference in anxiety between the classroom-related and the learning-related situations (z = −1.812, p > 0.05).

Correlation coefficients between emotions were calculated to see how those emotions were related to each other (Table 4). As expected, positive achievement emotions (enjoyment, pride) were significantly and highly correlated with positive emotions, while negative emotions were significantly highly correlated with negative emotions (boredom, anger, shame, anxiety, and hopelessness). Interestingly, there was an exception in which a negative emotion was significantly correlated with a positive emotion; boredom was significantly (statistically) correlated with enjoyment.

Table 4. Correlations between Achievement Emotions.

| Enjoyment | Pride | Boredom | Anger | Shame | Anxiety | Hopelessness |
|-----------|-------|---------|-------|-------|---------|--------------|
| Enjoyment | 1     | 0.87 *  | 0.41 * | 0.13  | 0.27    | 0.31         | 0.22         |
| Pride     | 1     | 0.26    | 0.14  | 0.10  | 0.22    | 0.14         |
| Boredom   | 1     | 0.64 *  | 0.59 * | 0.10  | 0.22    | 0.14         |
| Anger     | 1     | 0.72 *  | 0.82 * | 0.83 * | 0.84 *  |
| Shame     | 1     | 0.89 *  | 0.84 * | 0.94 * | 1       |
| Anxiety   | 1     | 0.84 *  | 0.94 * | 1     |
| Hopelessness | 1 | 1 | 1 | 1 | 1 |

Note: * p < 0.05.

3.3. Correlations between Science Identity and Achievement Emotions

Participant students’ responses to the AEQ-p and selected items from the PRiSE survey were analyzed to investigate the relationship between their achievement emotions.
in physics and their science identity (biology, chemistry, physics). Table 5 shows the correlation results between the two measures. Students' self-identification as physics persons were significantly and negatively correlated with three negative emotions—anger, anxiety, and hopelessness. Moreover, their perceptions of their parents' /relatives'/friends' views of them as physics persons were significantly and negatively correlated with four negative emotions—anger, shame, anxiety, and hopelessness. Those results indicated that as students' self-identification as physics persons became lower, their feelings of anger, anxiety, and hopelessness increased. Furthermore, as their perceptions about their parents'/relatives'/friends' views of them as physics persons became lower, their feeling of shame related to physics-class, learning and tests increased, as did their feelings of anger, anxiety, and hopelessness. In terms of relationships with positive emotions, correlation coefficients between physics identity and enjoyment and between physics identity and pride were positive, although they were not statistically significant. This result implies that as participants' perceptions of themselves as physics persons increased, their enjoyment of and pride in physics increased. Those results indicated that students' self-identification as physics persons were intertwined with their achievement emotions in physics. In terms of students' self-identification and their perceptions of others' views of them as biology or chemistry persons were not significantly related to their achievement emotions in physics.

Table 5. Correlations between Student Achievement Emotions and Science Identity.

|                      | Enjoyment | Pride | Boredom | Anger | Shame | Anxiety | Hopelessness |
|----------------------|-----------|-------|---------|-------|-------|---------|--------------|
| **Yourself**          |           |       |         |       |       |         |              |
| Biology              | −0.20     | −0.07 | −0.14   | −0.14 | −0.20 | −0.15   | −0.08        |
| Chemistry            | −0.26     | −0.26 | 0.00    | −0.07 | −0.14 | −0.160  | −0.09        |
| Physics              | 0.39      | 0.39  | −0.250  | −0.42 *| −0.38 | −0.42 *  | −0.49 *      |
| **Parents/Relatives/ Friends** |       |       |         |       |       |         |              |
| Biology              | −0.25     | 0.14  | −0.23   | −0.18 | −0.29 | −0.21   | −0.18        |
| Chemistry            | −0.36     | −0.33 | −0.08   | −0.13 | −0.24 | −0.27   | −0.19        |
| Physics              | 0.83      | 0.30  | −0.33   | −0.48 *| −0.50 *| −0.58 *  | −0.60 *      |
| **Teacher/Professor** |          |       |         |       |       |         |              |
| Biology              | −0.03     | −0.06 | −0.11   | −0.18 | −0.15 | −0.20   | −0.16        |
| Chemistry            | 0.37      | 0.29  | −0.08   | −0.30 | −0.21 | −0.23   | −0.27        |
| Physics              | 0.37      | 0.29  | −0.08   | −0.30 | −0.21 | −0.23   | −0.27        |

Note: *p < 0.05.

3.4. Correlations between Student Achievement Emotions and Physics Identity in Three Pedagogical Situations

Next, relationships between students’ emotions and their physics identities in three pedagogical situations—class-related, learning-related, and test-related—were investigated. Table 6 presents correlation coefficients between the two measures in three different situations. The results showed that as students’ perceptions of themselves as physics persons became higher, their perceptions of others (parents, relatives, friends, and teachers) seeing them as physics persons became also higher. In the learning-related situation, we found statistically significant and positive relationships between students’ physics identity and their enjoyment, while relationships between their physics identity and their anger, shame, and anxiety were significantly negative. In the test-related situation, their physics identity and pride were significantly and positively related, while there were significant and negative relationships between their physics identity and their shame and between their physics identity and feelings of hopelessness.
### Table 6. Correlations between Students’ Emotion and their Physics Identity in Three Pedagogical Situations.

| Identity | Classroom | Learning | Test |
|----------|-----------|----------|------|
|          | Self      | P/R/F    | T/P  |
|          | E         | P        | B    | A    | S    | An   | E    | P    | A    | S    | An   | H    |
| Self     | 1         | 0.78 *   | 0.63 *| 0.37 | 0.37 | −0.27| −0.40| −0.13| −0.39| 0.45 *| 0.26 | −0.22| −0.44 *| −0.43 *| −0.48 *| 0.26 | 0.43 *| −0.38| −0.43 *| −0.37| −0.49 *| −0.49 *|
| P/R/F    | 1         | 0.50 *   | 0.12 | 0.01 | −0.39| −0.46 *| −0.32| −0.59 *| 0.14 | −0.01| −0.23| −0.48 *| −0.53 *| −0.60 *| −0.09| 0.09 | −0.46 *| −0.49 *| −0.53 *| −0.60 *| −0.60 *|
| T/P      | 1         | 0.40     | 0.38 | −0.21| −0.34| −0.11| −0.25| 0.28 | 0.21 | 0.04 | −0.23| −0.37 | −0.25 | 0.21 | 0.19 | −0.24| −0.09 | −0.20 | −0.27 |
| Identity | E         | 1        | 0.71 *| 0.30 | −0.06| 0.19 | 0.20 | 0.81 *| 0.76 *| 0.37 | 0.12 | 0.21 | 0.18 | 0.78 *| 0.69 *| 0.16 | 0.27 | 0.33 | 0.18 |
|          | P         | 1        | 0.27 | 0.12 | 0.03 | 0.11 | 0.71 *| 0.87 *| 0.21 | 0.13 | −0.03 | 0.12 | 0.72 *| 0.64 *| 0.11 | 0.02 | 0.23 | 0.14 |
|          | B         | 1        | 0.63 *| 0.56 *| 0.57 *| 0.30 | 0.36 | 0.87 *| 0.65 *| 0.58 *| 0.57 *| 0.50 *| 0.14 | 0.70 *| 0.53 *| 0.63 *| 0.62 *| 0.13 |
|          | A         | 1        | 0.70 *| 0.70 *| 0.02 | 0.21 | 0.49 *| 0.88 *| 0.55 *| 0.78 *| 0.31 | −0.02| 0.87 *| 0.54 *| 0.72 *| 0.77 *| 0.76 *| 0.69 *| 0.09 |
|          | S         | 1        | 0.73 *| 0.17 | 0.20 | 0.45 *| 0.69 *| 0.72 *| 0.66 *| 0.45 *| 0.23 | 0.76 *| 0.68 *| 0.67 *| 0.62 *| 0.18 | 0.16 |
|          | An        | 1        | 0.18 | 0.28 | 0.47 *| 0.76 *| 0.84 *| 0.92 *| 0.37 | 0.09 | 0.80 *| 0.84 *| 0.94 *| 0.87 *| 0.16 |
|          | E         | 1        | 0.78 *| 0.3 | −0.02 | 0.14 | 0.10 | 0.76 *| 0.65 *| 0.09 | 0.08 | 0.29 |
|          | P         | 1        | 0.25 | 0.25 | 0.18 | 0.27 | 0.76 *| 0.66 *| 0.28 | 0.17 | 0.41 *| 0.31 |
|          | B         | 1        | 0.57 *| 0.47 *| 0.50 *| 0.49 *| 0.13 | 0.64 *| 0.53 *| 0.55 *| 0.56 *| 0.79 *|
|          | A         | 1        | 0.60 *| 0.87 *| 0.36 | 0.06 | 0.86 *| 0.66 *| 0.77 *| 0.79 *| 0.79 *| 0.79 *|
|          | S         | 1        | 0.80 *| 0.37 | 0.10 | 0.72 *| 0.86 *| 0.84 *| 0.78 *| 0.78 *| 0.78 *| 0.78 *|
|          | An        | 1        | 0.35 | 0.02 | 0.85 *| 0.84 *| 0.93 *| 0.92 *| 0.92 *| 0.92 *| 0.92 *| 0.92 *|
|          | E         | 1        | 0.81 *| 0.33 | 0.24 | 0.46 *| 0.29 |
|          | P         | 1        | −0.02 | 0.06 | 0.12 | −0.08 |
|          | A         | 1        | 0.79 *| 0.82 *| 0.89 *| 0.89 *| 0.89 *| 0.89 *| 0.89 *| 0.89 *| 0.89 *| 0.89 *|
|          | S         | 1        | 0.86 *| 0.86 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *|
|          | An        | 1        | 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *|
|          | H         | 1        | 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *| 0.94 *|

Note: * p < 0.05, 1 P/R/F = Parents/Relatives/Friends, 2 T/P = Teachers/Parents, 3 E = Enjoyment, 4 P = Pride, 5 B = Boredom, 6 A = Anger, 7 S = Shame, 8 An = Anxiety, 9 H = Hopelessness.
As we expected, students’ positive emotions were, overall, positively related to positive emotions in the three situations. Moreover, their negative emotions were positively related to each other in the situations. This finding indicated that students’ positive and negative achievement emotions seemed to be consistent across the three pedagogical situations. However, there were exceptions in which positive emotions were significantly and positively related to negative emotions: boredom in a classroom-related situation and enjoyment in a test-related situation ($r = 0.50^*$), pride in a classroom-related situation and anxiety in a test-related situation ($r = 0.41^*$), and enjoyment and anxiety in a test-related situation ($0.46^*$). The three cases had in common that at least one of the two emotions was in the test-related situation, implying that the test-related situation could provide a context where students’ achievement emotions could be different from the other two situations.

4. Discussion

Students’ emotions in class are not separable from their learning achievement and self-identification. The aim of this study was to investigate students’ achievement emotions in an inquiry-based physics class and their science identities, and to explore relationships between the two. We especially focused on students’ physics identity as their self-identification as science persons.

Overall, students’ self-identification as biology/chemistry/physics persons showed a pattern similar to their perceptions of others’ (parents, relatives, friends, teacher, and professor) views of them as science persons. This implies that their self-identification was, overall, consistent with their perceptions of others’ views of them as science persons. By dividing the rating scales (1–6) into two categories, low level (1–3) and high level (4–6), we could compare students’ self-identification as science persons in a simpler way. The result illustrated that students rated themselves as chemistry or physics persons at the low level more often than at the high level, indicating overall low science identity for college students. Among those three disciplinary areas, students’ identity as physics persons was the lowest. Interestingly, although we surveyed students’ science identities in physics class, their physics identity was lower than the other two: biology and chemistry identities. This result is aligned with the finding of a previous study [25] that, overall, students had low science identity and depressing views toward physics. Even though the current study was conducted in an inquiry-based physics class, the result was similar to the previous study, which was conducted in a non-inquiry-based class. However, students’ self-identification as biology persons was not particularly in favor of either the low or the high level. A future study could further this finding by exploring why college students’ biology identity was not as low as their self-identification as persons in the other science disciplines. It could be due to the fact that biology, at least at the introductory level, does not require mathematical competencies. Moreover, chemistry and physics college courses introduce many abstract concepts such as force, potential energy, momentum, and nonvisible particles, and students might have difficulty understanding those concepts and seeing themselves as chemistry or physics persons.

In terms of their achievement emotions in physics, overall, students had high negative emotions such as anxiety and hopelessness. This finding became evident when the data was divided into three pedagogical situations: class-related, learning-related, and test-related. Given that items addressing anxiety were included in all three situations, students’ anxiety emotions were compared using nonparametric statistics (the Wilcoxon matched paired test). The result showed that, overall, students’ anxiety levels were significantly increased in the test-related situation compared to the class-related and learning-related situations. This finding is not surprising, but the degree of increase in anxiety in the test-related situation is interesting. Another interesting finding was that anxiety in the test-related situation was significantly and positively related to enjoyment in the same situation. The control-value theory views emotions as sets of interrelated affective, cognitive, motivational, and physiological components. Thus, anxiety consists of uneasy and tense feelings (affective), worries (cognitive), impulses to escape (motivational), and peripheral activation (physiological) [10].
Our result implies that anxiety was triggered intensively in the test-related situation, but this anxiety might not hinder students’ feeling of enjoyment in the situation. We note that given the small number of items for “Enjoyment” in the test-related situation (n = 3), those items may not fully represent students’ enjoyment in the test-related situation.

Thus, we further analyzed the data using correlation statistics to see how those emotions were related and what the relationships between students’ emotions and science identities were. As we expected, positive emotions were positively connected to each other. In other words, as students felt more enjoyment, their pride was also high. This pattern was consistent across the three pedagogical situations, meaning that we found positive and significant relationships between enjoyment and pride in all three situations. Negative emotions also were positively and significantly related to each other in all three situations.

In terms of relationships between students’ science identity and their achievement emotions, their physics identity was significantly related to their emotions in physics, which is not surprising; however, a notable finding was that their self-identification as physics persons was statistically significantly and negatively related to negative emotions such as anger, anxiety, and hopelessness. Students’ perceptions of their parents’/relatives’/friends’ views of them as physics persons were also significantly and negatively correlated with negative emotions such as anger, shame, anxiety, and hopelessness. Here, the emotion shame was found to be statistically significantly in relation to perceived parents’/relatives’/friends’ views of the student as a physics person. However, there was no statistically significant correlation with perceived teacher’s/professor’s view of students’ physics identities. This finding indicated that the way students viewed themselves and their perceptions about how their close people viewed them as physics persons were statistically significantly in relation to their negative emotions. That means as students identified themselves and their close people identified them as physics persons at higher levels, students’ negative emotions about physics tended to get lower. As we previously pointed out, students’ physics identity was the lowest, although we surveyed their science identity in a physics class. In addition, while there were no significant correlations between students’ other identities (chemistry, biology) and achievement emotions in physics, their physics identity was significantly correlated with their achievement emotions. This finding implies that students’ lower physics identity could affect their achievement emotions in physics and vice versa. By contrast, students’ other identities (chemistry, biology) were not significantly correlated with their achievement emotions in physics, implying that students’ identities in a specific science disciplinary area (i.e., physics, chemistry, or biology) could contribute to their attitudes towards the discipline but not towards other science disciplines. In other words, students’ achievement emotions in a specific discipline could be related to their perceptions as a person in the disciplinary area.

This pattern was confirmed when we analyzed the data using three different situations. When students identified themselves as physics persons, their enjoyment of the learning-related situation tended to be higher, while their anger, shame, and anxiety in the same situation became lower. In the test-related situation, their pride increased and their shame and hopelessness decreased as they viewed themselves more as physics persons at a higher level. Interestingly, students’ perceptions about their close persons’ views of them as physics persons were significantly related to their negative emotions in the three situations. To be specific, the more they perceived that their parents/relatives/friends viewed them as physics persons, the less they felt anger and anxiety in the classroom-related situation and anger, shame, and anxiety in the learning- and test-related situations. Their feelings of hopelessness also decreased as their perception of those people’s positive views of them as physics persons increased. It was interesting that we found a statistically significant correlation between anxiety and self-identification as physics persons in the learning-related situation, while anxiety was significantly related to perceived parents’/relatives’/friends’ views of them as physics persons in all three situations. In addition, correlation coefficients between the students’ perceived parents’/relatives’/friends’ views of them as physics persons and negative emotions were all higher than those between their self-identification
as physics persons and negative emotions. These results are important in that they showed the importance of students’ perceptions about their close people’s views of them as physics persons as a potential factor affecting their achievement emotions in physics. Of course, it is possible that their negative emotions might be factors that affect their perceptions about their close people’s views. In the current study, a causal relationship cannot be determined, but given that their perceived close people’s views of them as physics persons might have been established before they entered their college classrooms, those views could be a cause of negative emotions rather than a result of the negative achievement emotions.

The findings also presented a unique context of the test-related situation that affected students’ emotions. In the other two situations, students’ positive emotions were statistically significantly and positively related to each other. On the other hand, in the test-related situation the pattern was not consistent. For example, as students felt more pride in the learning-related situation, they felt more anxiety in the test-related situation with statistical significance. As we described earlier, anxiety in the test-related situation was significantly and positively related to the enjoyment in the same situation. This finding indicated that the physics test-related situation provided a unique context different from the learning- and class-related situations. Students’ test anxiety could affect their performance on their tests [26,27] regardless of their positive emotions in physics. This result also implies that test anxiety could be triggered for students regardless of their performance, as we found that students who had high pride in learning physics could also have high anxiety about physics tests. In order to provide a supportive and safe environment in a test situation, physics instructors may need to be aware of this finding that students’ high anxiety in physics tests could be triggered regardless of their positive emotions about learning physics.

In our study, we found that two negative emotions—anger and hopelessness—were significantly related to all negative emotions across the three situations with statistical significance, but that they were not significantly related to any positive emotions. However, although the positive emotions were significantly and positively related to each other, we found cases in which a positive emotion was significantly related to a negative emotion, e.g., pride in the learning-related situation and anxiety in the test-related situation. Moreover, there were cases in which enjoyment was significantly related to boredom in the class- and learning-related situations, shame in the class-related situation, and anxiety in the test-related situation, where the enjoyment was in the test-related situation. This implies that test-related enjoyment could not be mutually exclusive with the three negative emotions. According to control-value theory, achievement emotions can be distinguished according to their valence (positive/negative). This indicated that enjoyment can be distinguished from anxiety, shame, or boredom; and the positive emotion could be incompatible with negative emotions [10]. However, in our study, test-related enjoyment was not always distinguished from negative emotions; rather, it could be positively related to them. This finding should be confirmed by future studies by administering the questionnaire to a larger and more diverse group of students. We note that the number of items for each emotion was not the same across the three different situations. In some cases, only two items were developed to represent a specific emotion; thus, the result should be interpreted with caution. For example, items representing “shame” in the class-related situation are only two; thus, they might not represent a broad range of students’ feelings of shame in the context of their physics class. Nonetheless, within the domain of achievement emotions as Pekrun et al. [22] designed it, this finding is interesting insofar as test-related enjoyment could be compatible with negative emotions in the test-related situation.

In summary, this study found that students’ self-identification and perceptions about their parents’/relatives’/friends’ views of them as physics persons were significantly related to their achievement emotions in physics. Thus, helping students build their self-identification as physics persons could also increase their achievement emotions in physics. This study also found that, depending on the pedagogical situation, positive emotions could be positively related to negative emotions, meaning that those two types of emotions might be mutually exclusive and not clearly distinguishable. Lastly, we found that tests
triggered great anxiety for students regardless of their pride in and enjoyment of physics, implying that test anxiety is not only for students who are low performers. It is possible that a high performer in physics could have high test anxiety in physics, meaning that providing a safer test environment or nontraditional types of tests such as performance assessments would be desirable.

A limitation of the study is that the number of participant students was small (n = 25). Moreover, this study was conducted in an inquiry-based physics course, and thus the findings of the study cannot be generalized. In order to generalize the findings, the questionnaire should be administered to a larger group of students across different formats of physics course, such as inquiry-based classroom, active learning classroom, and traditional classroom. This suggests a future study implementing the questionnaire in those larger and more diverse settings. We modified AEQ-M to investigate students’ achievement emotions in physics. In the questionnaire, there were cases where the number of items representing a type of emotion were less than three (see Table 3). Thus, it would be possible that those small number of items might not be enough to fully represent the emotion. Therefore, the results should be interpreted carefully within the domain of emotions defined by the original authors of AEQ-M [22].

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board at Texas Tech University under IRB2021-699 (approved on 8 November 2021).

**Informed Consent Statement:** Participants written consent was waived due to IRB approval as an Exempt study, presenting minimal risk to study participations.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author.

**Conflicts of Interest:** The author declares no conflict of interest.

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