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Shifting Educational Paradigms: An Analysis of Evolving Student Expectations within a Reformed Physical Chemistry Curriculum

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SHIFTING EDUCATIONAL PARADIGMS: AN ANALYSIS OF EVOLVING STUDENT EXPECTATIONS WITHIN A REFORMED PHYSICAL CHEMISTRY CURRICULUM

by

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ABSTRACT

Students often hold negative expectations when enrolling in rigorous undergraduate courses. Physical Chemistry is a challenging upper-level course for Chemistry majors; the course has a reputation as a demanding course that leads to students building negative expectations. This worsened when ambiguity existed in an instructor's pedagogy. Not addressing those initial expectations of the students abates their motivation, which does not put them in the best place to learn, leading to poor academic performance. The course syllabus is often the first interaction a student has with the course; it can be a critical tool in (re)setting students' initial expectations and allows the instructor to create a teaching plan that will indicate what the students should anticipate in the course. However, discrepancies between students' initial expectations and lived experience of the course may lead students to develop a negative perception of the course and perform poorly. This study addresses this issue by using the syllabus's content as a learning tool to adjust students' expectations, create transparency on behalf of the instructor, and use a reformed pedagogy. This new course structure is introduced by shifting the course from instructor-centered to a more effective teaching method, Process-Oriented-Guided-Inquiry-Learning (POGIL). Rather than being instructor-centered, POGIL focuses on a learning-centered experience for students. This allowed participants to engage more with others via group work while encountering complex concepts in the course. This study collected responses from Physical Chemistry students via three Qualtrics surveys using Likert-Scale questions. The surveys evaluated how students' expectations shifted before reading the syllabus (initial expectation), after oriented to the reformed pedagogy (new/evolved expectation), and finally at the end of the course (experience).

The Wilcoxon Mann-Whitney nonparametric test was used to analyze survey results and to recognize significant shifts in student expectations after exposure to POGIL. This revealed that before syllabi were distributed, most students expected a conventional instructor-centered course structure rather than a reformed pedagogy. In addition, this highlighted specific components in the reformed syllabus responsible for the shift in students' expectations. This could help instructors leverage their syllabus to accurately convey the experience students should expect when entering a course with a reformed pedagogy. Students' expectations shifted in the intended direction after orientation. However, most of their experiences by the end of the course failed to meet their expectations due to the limitations experienced. The implications from the results can be used to address the limitations encountered, which will allow students' expectations to align with their experiences after shifting their negative perceptions toward the course. Addressing students' negative expectations at orientation will help mitigate misconceptions about the course and help align their expectations and gained experiences. This will place students in the best position to learn from the beginning so they may be successful in Physical Chemistry.

ACKNOWLEDGEMENTS

I want to express my thanks and extend my deepest gratitude to Dr. Julie Donnelly & Dr. Tamra Legron-Rodriguez. This paper would have never seen the light of day or reached its potential had it not been for their mentorship and kindness. I owe the success of our thesis to them both. I hope that one day, I will earn the privilege to guide and impact a student's life just as they have done for me.

DEDICATION

This thesis is dedicated to my family, who I am nothing without.

To my mother, Carla, who left everything she knew and sacrificed everything so that I may find my path. Te amo, mami.

To my older brother, Ares, who overcame incredible challenges and sacrificed his dreams so that I may follow mine. I love you man.

To my little sister, Megan, my light, my drive, and the reason why I get up in the morning. I love you and promise to care for you until my last electron.

To my deceased father, Eddie, the hardest-working person I have ever met and whose example I try to follow every day. Te amo, papá, y te extraño cada día.

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INTRODUCTION

Undergraduate students pursuing a degree in Chemistry are often required to take Physical Chemistry after satisfying the prerequisite skills needed for the major, such as Calculus, General Chemistry, and Physics. Physical Chemistry is an upper-level course notorious amongst the Chemistry community for its rigorous curriculum and challenging concepts. With the course holding such a reputation in the academic community, students entering Physical Chemistry can build a negative perception toward the class. This perception is further developed in a course style that, despite being traditional, is ineffective in communicating or preparing students for the challenging concepts experienced in assignments or exams.

A study of changes in students' expectations in a course using reformed pedagogy showed a trend of students holding negative perceptions toward the course, leading to a lack of motivation from students (Carter et al., 1989; Wigfield et al., 2000). A few factors could be explored for being responsible for influencing the student's negative perception towards Physical Chemistry, such as the style of pedagogy the instructor practices during lectures and the course syllabus that is meant to set expectations which is prepared and distributed to students at the beginning of the semester (Sözbilir, 2004). Students reported that based on what they had gathered from their experiences in the course, they did not believe that their experiences matched what they expected. This raises concern about the communication on the instructor's side as well as the course design and which components of the course influenced the students not to have their expectations met.

The observed concerns helped shape the focus of this investigation to how students' negative expectations shift after being violated when exposed to a reformed Physical Chemistry pedagogy. With the aid of Qualtrics surveys, student's responses were recorded three times throughout the semester. The first was their initial expectation, the second was their reaction to the reformed syllabus (shifted expectation), and the final response was taken at the end of the semester. Survey responses will allow insight into how the syllabus influenced the students' expectations and which components were responsible for that shift.

Using an analytical framework, interactive inquiry, and reflective processes allows the study to adopt a methodology of research where via continuous observation a problem is identified, data is collected, and the problem is addressed, this is known as action research (Efron et al., 2020). The study is driven by student participants rather than the researcher's agenda; the faculty member uses their experiences, systematic observations, and interactive inquiry to investigate a real-life issue in their classroom. Once identified, data is collected throughout the semester and undergoes collaborative analysis to make data-driven practice improvements to provide future students with the best learning experience possible so they may achieve academic success in the course (Stringer et al., 2021). The data derived from the study will support the identified implications so an effective change in practice can be implemented at a broader scale.

Physical Chemistry is a challenging course, however, with the importance of being proficient in the concepts for success in the course and students who perceive the course as challenging, leading to them expecting themselves to perform poorly, it sparked an investigation in the community. This led to finding a new instructional strategy or practice that lowers the negative perception held toward the course by reducing the violation of students' expectations in the course from day one (Fox et al., 2015). This investigation will be responsible for gauging the effectiveness of the implemented reformed Physical Chemistry pedagogy in adjusting student's negative perceptions.

LITERATURE REVIEW

Undergraduate Student Perceptions of Physical Chemistry

A collection of survey responses, in addition to student performance in challenging courses, has revealed a need for more transparency behind the course structure, contributing to the low expectations and negative perceptions that students share for the upper-level Chemistry course (Nicoll et al., 2001). These views held by students have contributed to lower course performance due to multiple elements negatively impacting their learning.

Students notoriously know that physical chemistry has a rigorous curriculum, which is expected of an upper-division chemistry course (Carter et al., 1989). Instructors in the past have focused on systemic issues such as resources, accessibility, class size, and student background to help with the challenges of Physical Chemistry, while setting expectations early in the semester could help mitigate negative expectations from the students (Singer et al., 2012). The level of discrepancy between student and instructor regarding the expectations of the course is an obstacle that can impede a student's ability to succeed in the course, contributing to the negative perception held by students (Carter et al., 1989). A student's perception of Physical Chemistry courses is affected when an instructor and student have different views of what is required to make one successful in the course (Bain et al., 2014). This highlights the importance of the orientation and the activities given on that first day of class. It allows students and instructors to align their expectations for the course and its requirements. It is important to note that the first day of a lecture is typically not the first interaction the student has with the course. It is more common for the course syllabus to be the first interaction (Donnelly et al., 2021). A negative perception of the course will only lead to a student lacking motivation, contributing to declining performance (Gaffney et al., 2010).

Role of Course Syllabi in Undergraduate Courses

A course syllabus is traditionally a document distributed to students on the first day of class. It offers a comprehensive review of what is expected from the course and its structure. It allows the instructor to communicate with the student, such as how the course will develop throughout the semester, which text needs to be read in preparation for each respective lecture, and which assignments and grade weights to expect (Parkes et al., 2002). The course syllabus is commonly the first interaction the student has with the course, and it is the instructor's first opportunity to set a student's expectations and shift their perception. Due to this, it provides them with the ability to influence and set the expectations the students will have toward the course.

The level of discrepancy between student and instructor regarding expectations of the course is a factor that must be considered when developing the course syllabi due to the amount of time a student relies on the syllabus. The contents of a course syllabus set the expectations for the students in class and how they prepare for the class; this can affect how the student believes they will perform in the course, which can affect their negative perception of the course (Nicoll et al., 2001).

Students' perception of the course is most influential at the beginning of the semester as they are setting expectations based on assumptions and not experiences. Therefore, spending time on each syllabus component is essential to ensure there is as much transparency as possible between instructor and student, which helps avoid the expectations of students being violated throughout the semester, increasing their negative perception towards Physical Chemistry, and assisting the instructor in mitigate negative expectations toward the course (Wigfield et al., 2000).

Like students, instructors benefit from using a well-structured syllabus as it can guide their course design to match the expectations of the students. This instrumental tool can help the instructor understand the course structure and what the students should expect from them. Gaining this understanding can benefit a student's performance, as course syllabi have traditionally been seen more as a contract than a tool for learning (Gaffney et al., 2010).

Conceptual Framework: Expectancy-Violation

As aforementioned, traditionally, undergraduate courses have consisted of instructor-centered classroom pedagogy, where class sessions consist of having an instructor lecturing in front of students. However, previous studies report evidence that instructor-centered classrooms used in undergraduate courses are no longer considered the most effective pedagogy for the education of students today and that learning-centered classrooms are being more accepted across campuses (Palmer et al., 2014; Wigfield et al., 2000).

The movement of faculties setting out to discover a reformed form of pedagogy has increased over the years due to an effort to mitigate the negative expectations of students entering a challenging course that notably aligns with the aim of this investigation, which is to reduce expectancy violations of undergraduate students taking Physical Chemistry (Fox et al., 2015; Parkes et al., 2002). A syllabus with components that do not align with an instructor's lesson plans or what a student expects can increase confusion, which factors into understanding how to prepare for the class effectively (Donnelly et al., 2021).

A previous study used an Expectancy-Violation assessment to reveal that as the semester progressed, there was increased vagueness and lack of transparency on the instructor's side due to the student's expectations not aligning with their experiences in class [14,15] (Wigfield et al., 2000; Wiggins et al., 1998). Even more, a student's expectation for themselves to be successful and how they view their worth in the course directly correlates with their motivation to learn; it can be challenging to stay motivated and even more successful in a course that continuously breaks and reduces initial expectations (Wigfield et al., 2000). Violating a student's expectations in a rigorous course, even more consistently, can be detrimental to their education, especially if the student has an initial negative perception of the course (Bain et al., 2014).

Research Questions

1) How does the course syllabus influence students' initial expectations in Physical Chemistry courses?
2) What components of the course syllabus reflect the student's shift in expectations in the Physical Chemistry course?

METHODOLOGY

Participants

Based on the number of enrolled students in the course, approximately sixty-five students participated in the study. Before participating, all the students verified that they are the age of eighteen or over. The participants that took part in the study were enrolled in 'Physical Chemistry I' at the University of Central Florida (main campus) during the Fall 2023 semester.

Ethical Consideration

All participants were informed that their choice to participate in the research study was voluntary. If they opted out of participating in the survey, they were told that they would not be penalized. The study did not involve activities that posed any risk or harm to participants. This investigation was approved by the University of Central Florida's Institutional Review Board (IRB).

Course Design

The Physical Chemistry course in this study was a Process-Oriented Guided Inquiry Learning (POGIL) course that fostered a learning-centered experience for students, allowing them to be more engaged with their peers via team-based practice (Gaffney et al., 2010). Students worked in assigned teams to complete assignments for a grade based on completion. They worked through guided questions and assignments to develop concepts; the activities were followed by a lecture on the topic.

Additional attention was paid to the course syllabus due to its importance to the study. This is due to the syllabi being the first interaction the student had with the new pedagogy, which provided the best opportunity to readjust the student's initial expectations. Therefore, to properly introduce them to the course, a rubric known as 'Measuring the Promise' was adapted from Palmer et al. (2014), not just to hold the study and instructor accountable for meeting the criteria for a learning-centered rubric but also to create a clear line of communication from the instructor to the students.

This course used a learning assistant (LA), a student who passed the course and supported learning in interactive pedagogical environments, such as POGIL. Their role was to walk around during small group activities, facilitating discussions while assisting and guiding students through complex concepts as needed throughout the class. Group assignments were a consistent component of the reformed course, and the tests provided were taken individually and as teams, with both scores contributing to the overall exam grade. Groups experienced challenging concepts throughout the semester, such as Excel plotting activities that require students to analyze data and interpret the mathematical models of chemical behavior. Experiencing complex concepts in a group setting allows for discussion and exchange of ideas to stimulate critical thinking (Gaffney et al., 2010).

Hypothesis

The data continuously collected from the students via the three surveys throughout the semester allowed us to perform an in-depth quantitative and statistical analysis. Using the data, we can determine how effective the reformed pedagogy and learning-centered syllabus was in adjusting the expectations of undergraduate Physical Chemistry students. If carried out properly, the negative perception towards the Physical Chemistry course should be mitigated, and by the end of the course, their experiences should align with their adjusted expectations.

Data Collection

Quantitative data collection was carried out using Qualtrics questionnaire surveys that used a Pedagogical Expectancy Violation Assessment (PEVA), which assesses student expectations and experiences to gauge the success of a newly integrated pedagogical reform. PEVA uses a Likert scale which was applied to the surveys in the study, this helped measure students' expectations towards Physical Chemistry and their experiences at the end of the course (Gaffney et al., 2010).

Survey Part I & II	
Part I: Indicate how often you expected to experience the following when you signed up for a Physical Chemistry Course.	Part II: Indicate the degree to which you agree or disagree with the following statements.
Very Infrequently (1) – Very Infrequently (7)	Strongly Disagree (1) – Strongly Agree (5)
• Lecture • A Grading Curve • **Collaborative (Group Discussions). *** • **Computer Modeling and/or Programming. *** • Doing Required Reading. • Missed Classes Would be Harmful to my Learning. • To Memorize Equations. • To Interact with my Instructor during Class Time. • **To Interact with my LA during Class Time. *** • **To Interact with my Peers during Class Time. *** • **To Explain my Work to the Class. *** • To Discuss my Work with Classmates during Class Time. • **To Discuss my Work with my Instructor or LA during Class Time. ***	• I Feel Confident Applying my Math Skills to Chemistry. • I Feel that I Have Sufficient Math to Succeed in this Course. • **I Look Forward to the Math Problems in this Chemistry Course. *** • I Think that I Should Review Concepts from Previous Math Courses. • I Think that I Should Review Concepts from Previous Chemistry Courses. • I Think this Class Will Have Too Much Math in it. • **I Feel Comfortable Seeking Help from Others to Clarify Difficult Material for me. *** • **I Feel Comfortable Explaining How I Solve Chemical Problems to Others.** • **I Feel That the Amount of Math in this Course Could Lower my Grade. *** • **I Enjoy the Challenges. *** • I am only taking this course because it is required. • The grade I receive in this course is less important than what I learn. • **I expect to learn a lot in this course.**

Table 1.0: (*) = Significant Statements (p-value <0.05)

The first set of questions (Part I) was derived from a research article by Gaffney (2010) that used expectancy violation to gauge how successful a reformed course design is. The Likert scale measures from 1-7, Very Infrequently (1), Infrequently (2), Somewhat Infrequently (3), Sometimes (4), Somewhat Frequently (5), Frequently (6), and Very Frequently (7), this was used to indicate how often a student experienced a given statement such as "Lecture" (**Table 1.0**). Students were asked to indicate how usually they expected to experience each statement when signing up for a Physical Chemistry course. The second set of questions (Part II) evaluated the students' initial perception of their math ability and confidence in applying their previous math knowledge to Chemistry (Nicoll et al., 2001). These questions were necessary to implement in the study as the involvement of advanced Calculus concepts in Physical Chemistry influenced the student's perception of the course. As seen in **Table 1.0**, these questions also used the Likert scale, but in a different manner. It measured from a 1-5 bipolar scale: Strongly Disagree (1), Disagree (2), Neither Agree nor Disagree (3), Agree (4), and Strongly Agree (5). Students were asked to indicate the degree to which they agreed or disagreed with the statement **(Table 1.0**). In addition, they were informed that the average time it takes to complete each survey was approximately 10 minutes and that all study data would be stored securely by the investigators. Using the University's resources available for all students and faculty through request, the Qualtrics software helped create three surveys distributed throughout the semester to gauge the shift in students' expectations and how it aligned with their experiences.

Procedure/Timeline

Figure 1.0: Timeline of the study.

Before the start of the semester, the research investigators prepared three surveys distributed at three different points throughout the semester (**Figure 1.0**). The first two surveys were both handed out on the day of orientation, however, at various points in time. The first survey was distributed at the beginning of class before being exposed to the course design and syllabus for the first time in person. It was crucial to distribute the survey the first day before they read the syllabus to capture their first reaction to the course structure accurately. The second survey was distributed to students after they took the first survey, were introduced to the course design, and handed a syllabus to read independently. The third survey was distributed near the end of the semester on the last exam day so as not to be mistaken for the final exam. By then, the student would have experienced most of the course-which allowed us to gauge their experience accurately. This was done by measuring the shift in expectations by comparing the data from surveys one and two, which allowed us to evaluate the effectiveness of our reformed pedagogy. After completing the last survey, all data was collected and prepared for statistical analysis.

Analysis

The first two surveys will be critical for analyzing the first research question, "How does the course syllabus influence the initial expectations of students in Physical Chemistry courses?" the Likert-scale survey questions from **Table 1.0** allow us to gauge how much their expectations changed from the first survey to the second survey from when the student participants were exposed to the new course design. All three surveys will be used to explore the second research question, "What components of the course syllabus reflect the student's experiences in the Physical Chemistry course?" looking at all responses will allow us to find which components from the new course design influenced the student's shift in expectations that attributed to their experiences throughout the semester.

Once all responses are collected from each survey, the data is processed and analyzed via the Wilcoxon-Mann-Whitney nonparametric test (Hollander et al., 1999). This test fits the need of the study as the ordinal data collected from the sample groups of interest (surveys) are predicted not to have a normal distribution as revealed by the means ($\overline{x}$) and standard deviation (σ). This is due to the belief that the expectations of the class as a whole will be skewed towards one side or the other (i.e., infrequent or frequent). The statistical test results will decide if the expectations of students were successfully shifted in the direction the study intended and determine which syllabus components were responsible for the significant (p-value <0.05) survey statements.

RESULTS

Overview

The distribution for each question is derived from the results of the PEVA learning tool, the x-axis represents the proportion or frequency of responses, and the stacked bars represent the surveys handed out throughout the semester (1, 2, 3). **Figures 12.0-13.0** are legends to color coordinate each type of response on the Likert scale for Part I and Part II survey statements. Survey 1 shows the students' initial expectations of the course, survey 2 shows the students' shift in expectations after being oriented to POGIL, and survey 3 displays their experiences gathered towards the end of the course. The Wilcoxon-Mann-Whitney nonparametric test by Hollander et al., (1999) helped compare the average ($\overline{x}$) and skewed distributions to their respective statements. Due to the low response rate ($n=9$) for survey 3, the nonparametric test was used to compare only surveys 1 and 2. Despite the low response rate recorded in survey 3, there was still an observed skewed distribution, which allowed all three surveys to be compared to prototypical patterns, this will be further discussed in a later section. This analysis was still effective in revealing which statements from Part I and II were significant (p-value <0.05). **Table 2.0-3.0** highlights the significance statements (*****) and the prototypical pattern the statement's distribution aligns with for part I and II survey questions. As mentioned, the responses from participants were anonymous; therefore, no student was tracked individually. It is important to note that the expectation shift is seen as the entirety of the class, not individually, as every student did not experience a shift in expectation.

Expectations

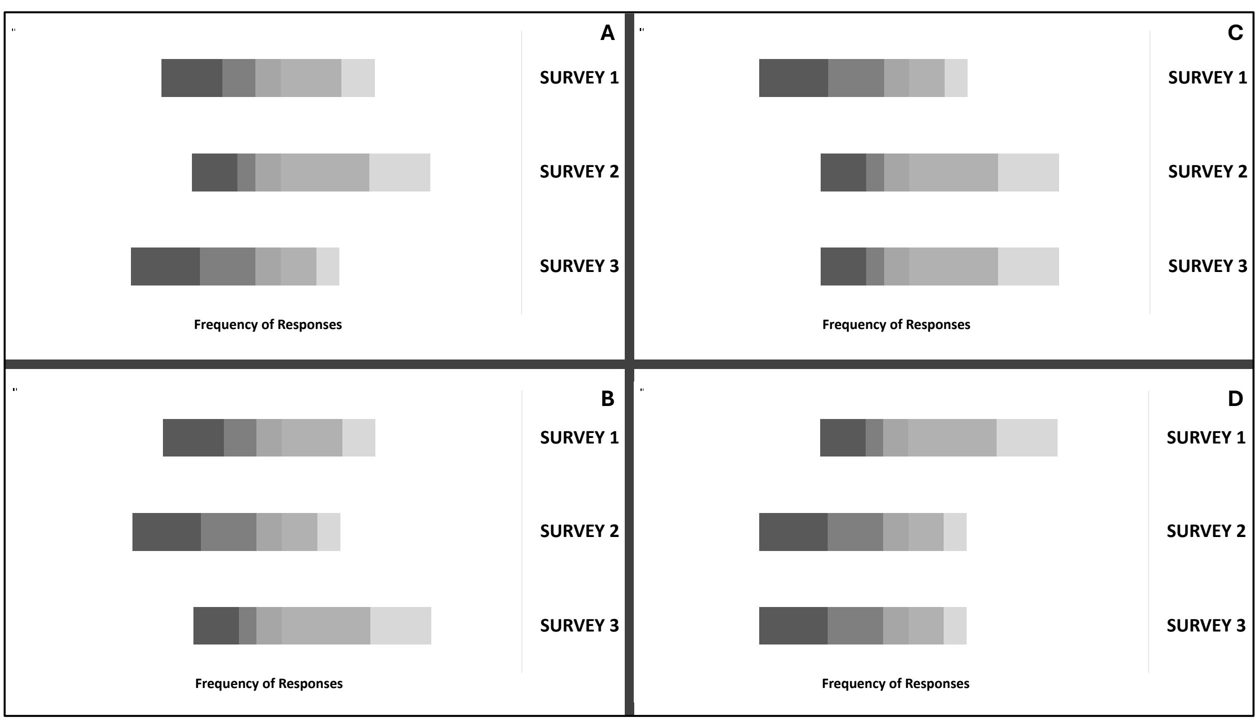
At first, students entering Physical Chemistry typically enter the class with orthodox views, such as expecting to sit and listen to the instructor's lecture for the duration of the class. However, PEVA revealed that once exposed to the study's reformed pedagogy (POGIL), students found the environment unfamiliar, which influenced their expectations for most statements, i.e., 'Lecture', 'Collaborative (Group Discussions)', and 'I Feel Comfortable Seeking Help from Others to Clarify Difficult Material for Me' **(Figures 7.0, 4.0, 5.0)**. In a traditional classroom, one would not expect to agree or experience the statements as frequently in a Physical Chemistry course however, POGIL contradicts that by fostering said statements. The students' initial expectations show that many were accustomed to conventional pedagogical practices, which placed the study in an excellent position to shift their initial expectations toward what one would expect to experience in a POGIL.

The Wilcoxon Mann-Whitney nonparametric test efficiently highlighted 13 statements from PEVA that had a significant shift in expectations, as shown in **Tables 2.0-3.0.** The non-significant statements did not display a perceptible change of expectations, meaning the students' expectations after being readjusted during orientation aligned with their initial expectations when entering class. Items i.e.: 'Doing Required Reading', 'Missed Classes Would be Harmful to My Learning', and 'I Think that I Should Review Concepts from Previous Math Courses', did not have a significant shift **(Figures 10.2, 10.3, 11.2)**, non-significant statements are found in **APPENDIX B**. This is expected as despite whether the Physical Chemistry students are in a traditional or reformed pedagogy, reading is essential to be prepared for success. Missing class would result in students being ill-prepared for midterms, and reviewing concepts before class will help prepare students for challenging concepts in any course. Therefore, this investigation focused on analyzing the significant survey statements from Part I and Part II.

Prototypical Patterns

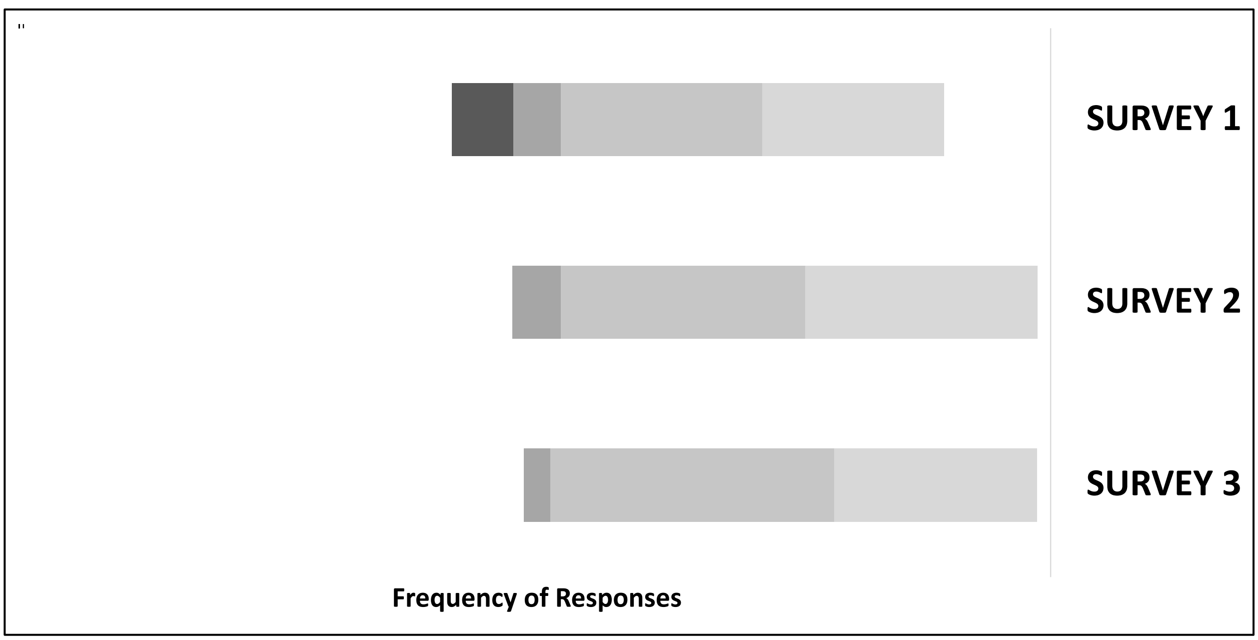
During orientation, students' expectations are typically adjusted by the instructor so that they understand the requirements of the course and how to prepare for it. Despite this assumption, students are not always oriented in the way the instructor intended, leading to them not being in the best position to learn or be successful in the course. This led to the study producing eight distinguishable prototypical patterns that compare how students' initial and shifted expectations align with their experiences for the significant statements. **Figures 12.0** and **13.0** display the color-coordinated legend for each Likert-Scale for each survey statement (Part I and II).

Figure 2.0. (a) Failure (Increasing Expectancy). (b) Failure (Decreasing Expectancy). (c) Success (Increasing Expectancy). (d) Success (Reducing Expectancy). The left of the x-axis represents (Infrequent/Disagree), and the right of the x-axis represents (Frequent/Agree).



Statements that match a successful pattern must meet certain qualifications, and their expectations after being oriented to the reformed pedagogy must shift in the intended direction of the study with their experiences aligning with their shifted expectations. There are two different ways successful patterns can be represented. **Figure 2.0 (c)** showed success in increasing students' expectancy and reported experiences by matching their shifted expectations. **Figure 2.0 (d)** represents success in reducing their expectancy with their experiences matching their expectations after orientation.

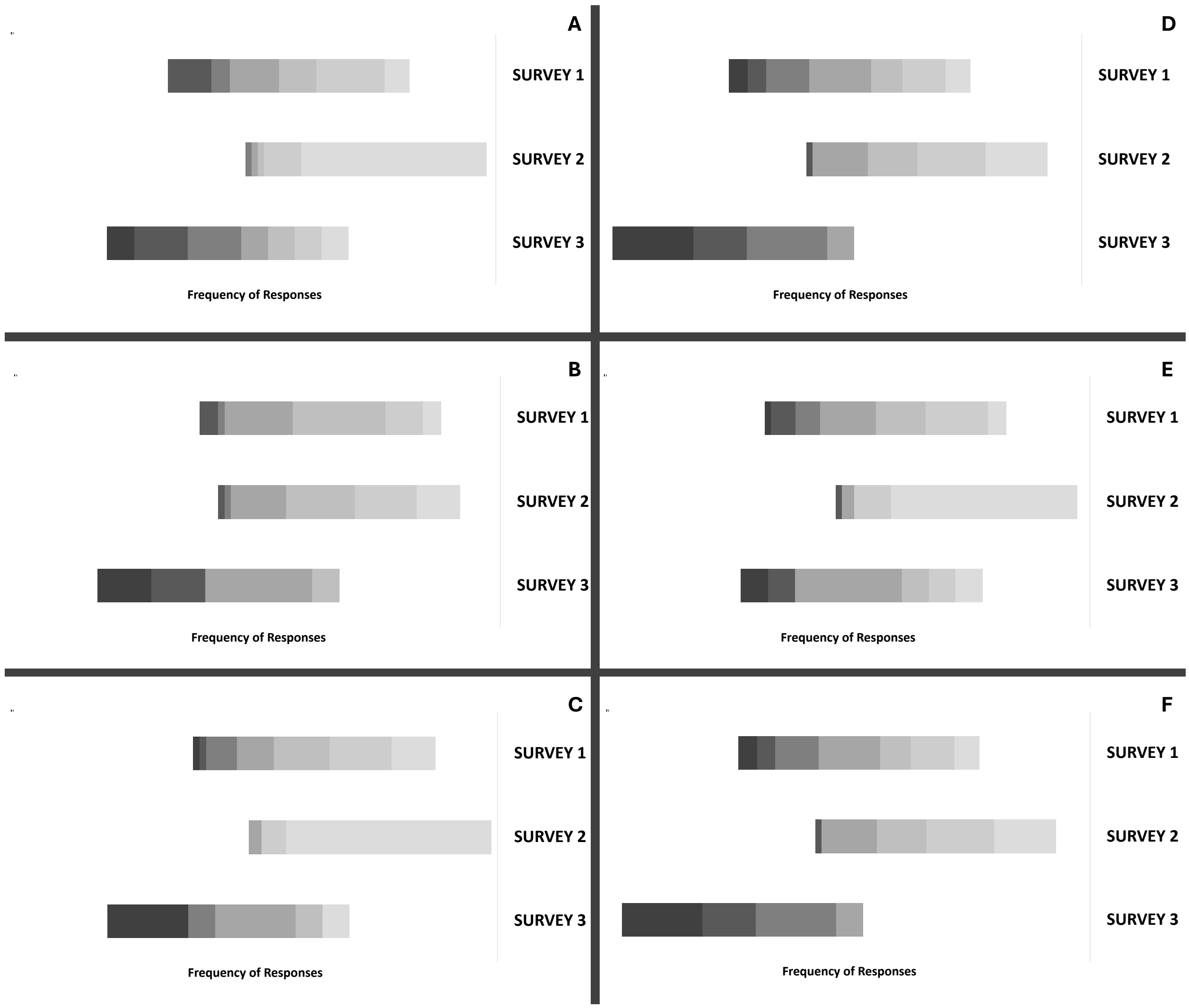
Figure 3.0. I Expect to Learn a Lot in this Course (Part II). The left of the x-axis represents 'Disagree', and the right of the the x-axis represents 'Agree.'



Only one of the significant statements matched a successful prototypical pattern, 'I expect to learn a lot in this course' **(Figure 7.12)** from Part II. After being oriented, the students' expectations were successfully shifted to increase their expectancy, matching their end-of-the-semester experiences.

Despite shifting students' expectations in the desired direction after orientation, not all their experiences aligned with what they expected. A failure prototypical pattern shows a discrepancy between shifted expectations and reported experiences, even if their expectations were shifted in the intended direction, this revealed that their experiences are the same or less than their initial expectations. **Figure 2.0 (a)** displays a failure to increase expectancy; their expectations shifted in the study's intended direction. However, the students' experiences did not only not align with their shifted expectations but were also less than or equal to their initial expectations before orientation. **Figure 2.0 (b)** has the same characteristics, however, it failed to reduce expectancy.

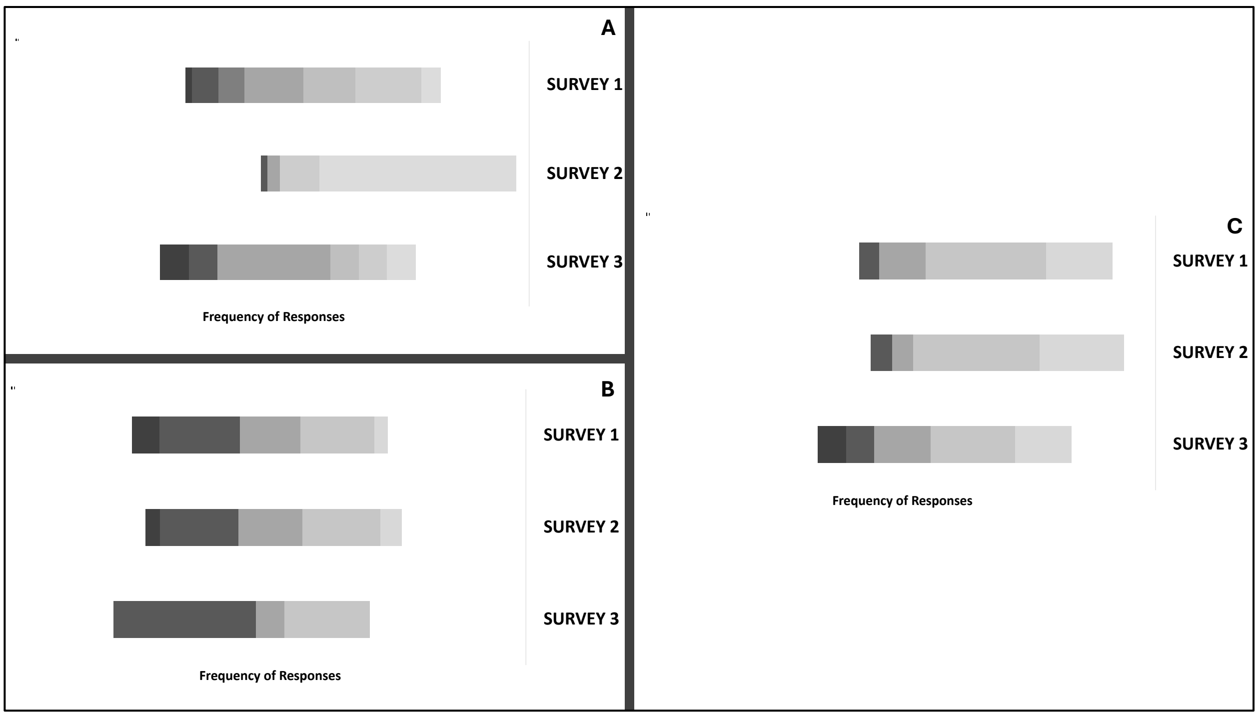
Figure 4.0. (a) Collaborative (Group Discussions). (b) To Interact with my LA during Class Time. (c) To Interact with my Peers during Class Time. (d) To Explain my Work to the Class. (e) To Discuss my Work with Classmates During Class Time. (f) To Discuss my Work with my Instructor or LA during Class Time. (Part I). The left of the x-axis represents (Infrequent/Disagree), and the right of the x-axis represents (Frequent/Agree).



Six significant statements from Part I and three from Part II are considered to follow a failure prototypical pattern. Failure patterns from Part I are: ‘Collaborative (Group) Discussions,’ ‘To Interact with my LA during Class Time,’ ‘To Interact with my Peers during Class Time,’ ‘To Explain my Work to the Class,’ ‘To Discuss my Work with Classmates During Class Time,’ and

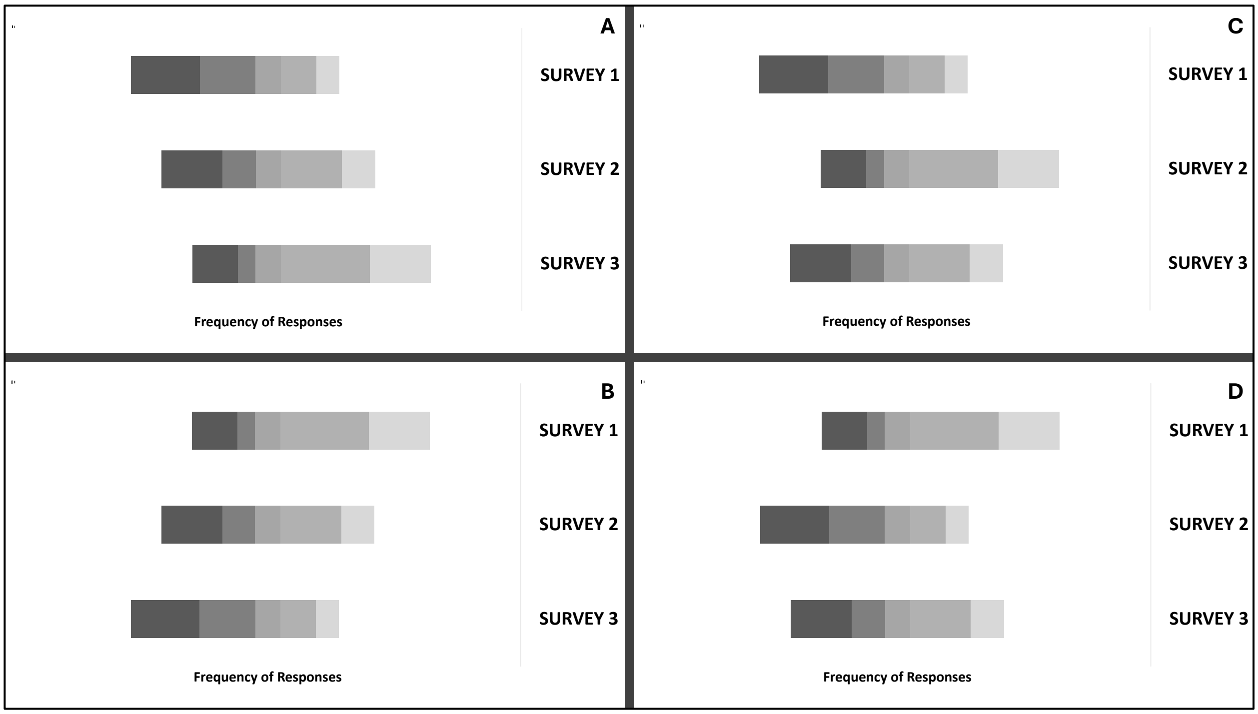
‘To Discuss My Work with my Instructor or LA during Class Time,’ all failed to increase expectancy **(Figure 4.0)**.

Figure 5.0. (a) I Feel Comfortable Seeking Help from Others to Clarify Difficult Material for Me. (b) I Feel That the Amount of Math inThis Course Could Lower My Grade. (c) I Enjoy the Challenges. (Part II). The left of the x-axis represents (Infrequent/Disagree), and the right of the x-axis represents (Frequent/Agree).



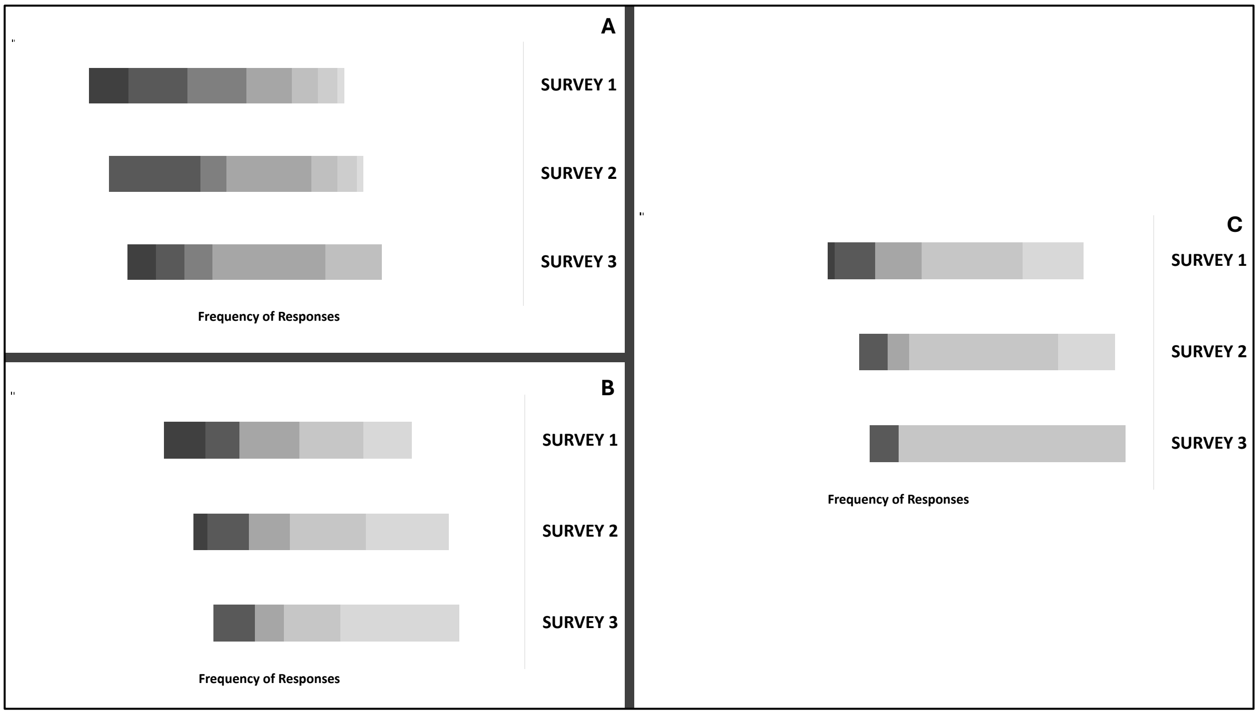
Part II statements: ‘I Feel Comfortable Seeking Help from Others to Clarify Difficult Material for Me,’ ‘I Feel That the Amount of Math in This Course Could Lower My Grade,’ ‘I Enjoy the Challenges’ (**Figure 5.0)**, these as well failed to increase the expectancy of students.

Figure 6.0. (a) Undershooting (Increasing Expectancy). (b) Undershooting (Reducing Expectancy). (c) Overshooting (Increasing) Expectancy). (d) Overshooting (Decreasing Expectancy). The left of the x-axis represents (Infrequent/Disagree), and the right of the x-axis represents (Frequent/Agree).



Like a failure, however not as dramatic, a statement that undershoots do not have reported experience aligning with the student's initial expectations even if they were shifted in the direction the study intended. The signature of this prototypical pattern is that expectations were appropriately shifted, but not to the extent that they matched with what they experienced in the course. This distribution is due to the orientation not being entirely effective in setting their expectations of what they will be experiencing in the class. **Figure 6.0 (a)** represents a statement undershooting to increase expectancy, and their expectations were increased as intended, but not to the extent where it matched their gained experiences. **Figure 6.0 (b)** is similar, however, this pattern undershoots to reduce expectancy.

Figure 7.0. (a) Computer Modeling and/or Programming. (b) I Look Forward to the Math Problems in this Chemistry Course. (c) I Feel Comfortable Explaining How I Solve Chemical Problems to Others. The left of the x-axis represents (Infrequent/Disagree), and the right of the x-axis represents (Frequent/Agree).



Three statements match this category, Part I: ‘Computer Modeling and/or Programming’ **(Figure 7.0 a)**; Part II: ‘I Look Forward to the Math Problems in this Chemistry Course’ and ‘I Feel Comfortable Explaining How I Solve Chemical Problems to Others’ **(Figure 7.0 b-c)**.

A statement that overshoots is when their reported experiences neither meet their initial nor readjusted expectations. The students were told to expect a particular component of POGIL however, the reformed pedagogy should have promoted the respective component more than the instructor had guaranteed. **Figures 6.0 (c,d)** represent prototypical patterns of overshooting in increasing and decreasing expectancy, respectively. No statement from this study aligned with an overshooting prototypical pattern.

Ultimately, our PEVA effectively measured students’ expectations and experiences in the course, providing information on which areas of the reformed pedagogy were effective and where we needed to pay extra attention. Using the outcome of the pedagogical assessment, the results allow for dialogue on how the course syllabus affected students' original expectations and if any components from the syllabus were responsible for the said shift.

DISCUSSION

Little to none of the results from the survey statements followed a successful distribution in reducing or increasing expectancy (**Figure 2.0 a,b).** However, that does not imply that the study's results were not meaningful. A positive trend across every PEVA significant statement revealed that the student's initial expectations successfully shifted in the direction the study desired. This evidence shows how orientation day was a critical stage in shifting students' expectations, even if most of their experiences did not align with their set expectations. Therefore, research question #2 was deprioritized and set aside due to the first one relating more to the results discussed. The communication between the instructor and students during orientation effectively created transparency about what is expected in a POGIL course. By the time they entered the upper-level course, most students had experienced multiple semesters, resulting in their conditioning to traditional pedagogical practices. The statements identified by the Wilcoxon-Mann-Whitney nonparametric test all support this claim. For example, **Figure (4.0 a)** shows that students did not expect collaborative group discussions because working with peers during class, especially in instructor-centered structures, is uncommon; therefore, after being oriented to the study's reformed pedagogy, students' expectations were successfully shifted from very infrequently (1) to very frequently (7) (Gaffney et al., 2010). When students need clarification on challenging material, they initially do not feel comfortable seeking help from peers, as working with others is not common in lectures (Singer et al., 2012). However, when exposed to the new course style, they were introduced to their groups for the semester and told to expect to collaborate with them often during the semester. A critical component of POGIL is its learning-centered structure, working together on complex concepts and relying on one another for clarification while guided by the instructor. This revelation is uplifting for the instructor by showing how positive the communication between both parties was during orientation day. Unfortunately, the results from Survey 3 (Part I, II) were not what the study hypothesized. Except for **Figure 3.0** (I Expect to Learn a Lot in this Course), none of the students' experiences aligned with what they expected from the class after being oriented to POGIL. This is mainly due to a few encountered limitations. A significant difference was identified in response rate between the surveys. Sixty-five students were enrolled in the class, however, due to tardiness and absences, the first two surveys (given on the same day) only had 39 students participate. Surveys 1 and 2 were provided in person, unlike survey 3, which was a take-home survey. This led to a low response rate, which resulted in nine responses. This led to the statistical test used to compare the distribution groups between the first two surveys. However, survey 3 was still valuable when determining which prototypical pattern supported each statement as the study viewed the shifts as a whole class, not individually. With this revelation, it was challenging to accurately gauge which specific syllabus components influenced the distribution of each survey statement.

The instructor can work on several improvement areas if the study continues or is replicated. For example, the level of comfort the students have when asked to explain how to solve chemical problems to others **(Figure 7.0 c)** undershoots to increase their expectancy. Despite not being classified as a 'failure,' the statement is like most other significant statements. They all are tied to working in groups in a learning-centered environment and failing to remain consistent. Working in teams was not as effective as believed throughout the semester, not every student had perfect attendance, and the accumulated absences affected the quality of groups. Working alongside peers is an integral component of POGIL, without teamwork, the reformed pedagogy will not be effective. This can be mitigated on orientation day by emphasizing the importance of attending class daily and having the instructor foster teamwork. However, not every limitation, such as student bias for conventional practices, can be fully addressed. One of the most considerable limitations this study encountered was the low response rate (n=9) of Survey 3. To address this, the instructor needs to provide Survey 3 in person, just like the first two, rather than allowing the students to take it home, and this will increase the response rate so their experiences may be more accurately measured.

Implementing new pedagogical practices is not limited to Physical Chemistry courses, and it can be applied to any course, even outside the sciences. PEVA was incredibly helpful in showing how successfully we adjusted students' negative perceptions toward our reformed pedagogy POGIL. If the limitations are addressed and traditional course structures shift toward a more learning-centered pedagogy, then students will be placed in the best position to learn and be successful in any course, even in Physical Chemistry.

APPENDIX A-SURVEYS

FIGURE 8.0

Expectancy-Violation Test (Part I)

1	2	3	4	5	6	7
Very Infrequently	Infrequently	Somewhat infrequently	Sometimes	Somewhat frequently	Frequently	Very Frequently

1. Lecture
2. A Grading Curve
3. Collaborative (group) discussions
4. Computer modeling and/or programming.
5. Doing required reading.
6. Missed classes would be harmful to my learning.
7. To memorize equations.
8. To interact with my instructor during class time.
9. To interact with my LA during class time.
10. To interact with my peers during class time.
11. To explain my work to the class.
12. To discuss my work with classmates during class time.
13. To discuss my work with my instructor or LA during class time.

Note. Survey questions adapted from, "*Do they see it coming? Using expectancy violation to gauge the success of pedagogical reforms*.", by Gaffney, J. D. H., Gaffney, A. L. H., & Beichner, R. J. (**2010**).

FIGURE 9.0

Expectancy-Violation Test (Part II)

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

1. I feel confident applying my math skills to chemistry.
2. I feel that I have sufficient math to succeed in this course.
3. I look forward to the math problems in this chemistry course.
4. I think that I should review concepts from previous math courses.
5. I think that I should review concepts from previous chemistry courses.
6. I think this class will have too much math in it.
7. I feel comfortable seeking help from others to clarify difficult material for me.
8. I feel comfortable explaining how I solve chemical problems to others.
9. I feel that the amount of math in this course could lower my grade.
10. I enjoy the challenges.
11. I am only taking this course because it is required.
12. The grade I receive in this course is less important than what I learn.
13. I expect to learn a lot in this course.

Note. Survey questions adapted from, *An Investigation of the Factors Influencing Student Performance in Physical Chemistry*", by Nicoll, G., & Francisco, J. S. (**2001**).

APPENDIX B-FIGURES & TABLES

FIGURE 10.0

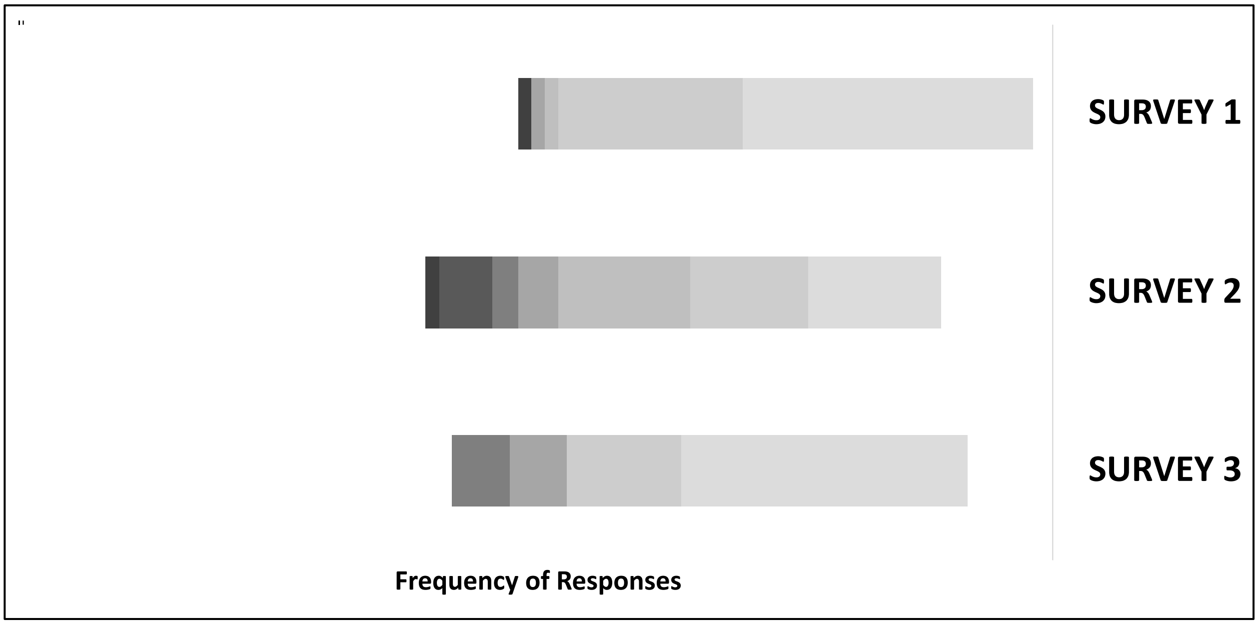


Figure 10.0 - Lecture (Part I) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 10.1

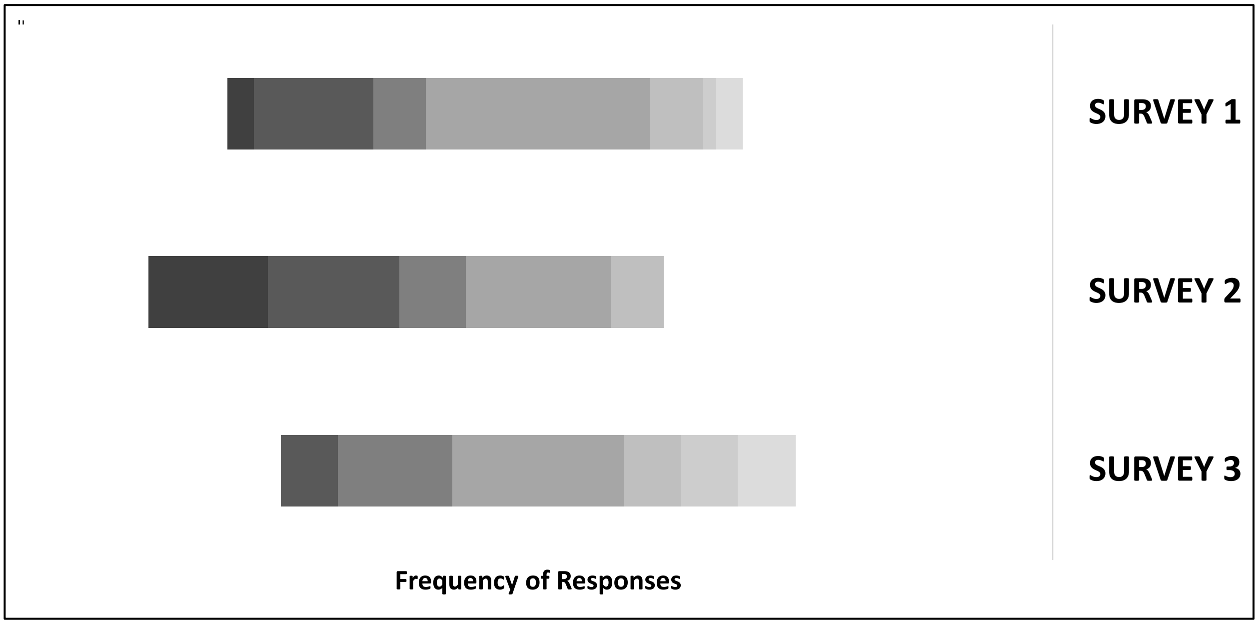


Figure 10.1 - A Grading Curve (Part I) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 10.2

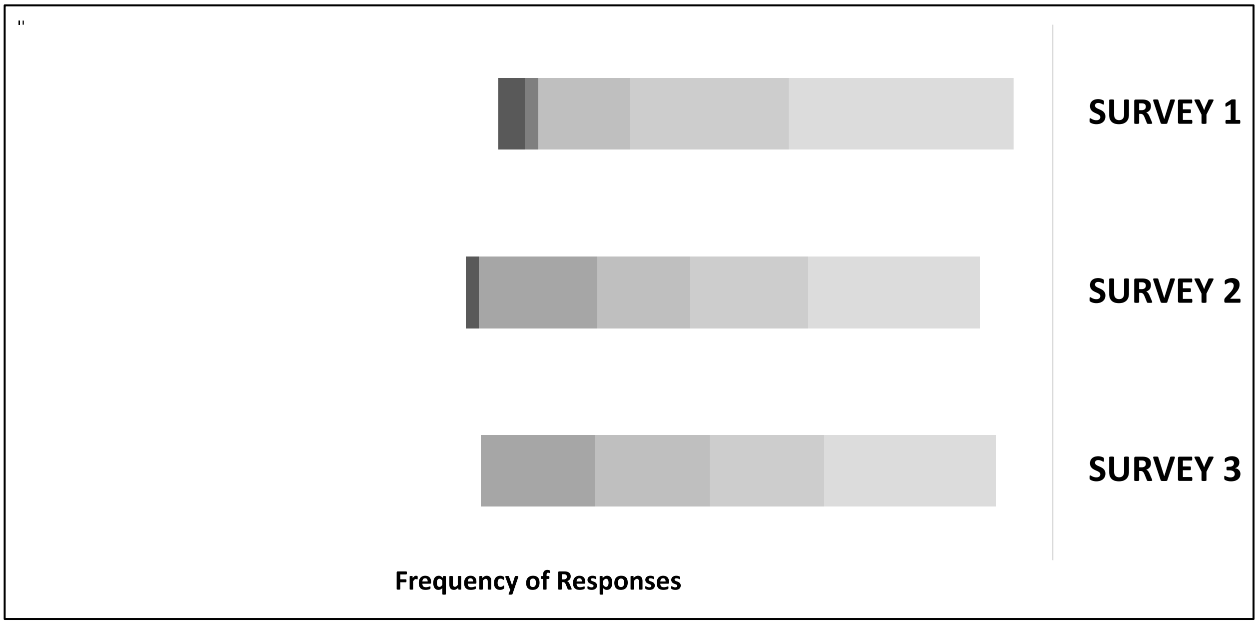


Figure 10.2 - Doing Required Reading (Part I) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 10.3

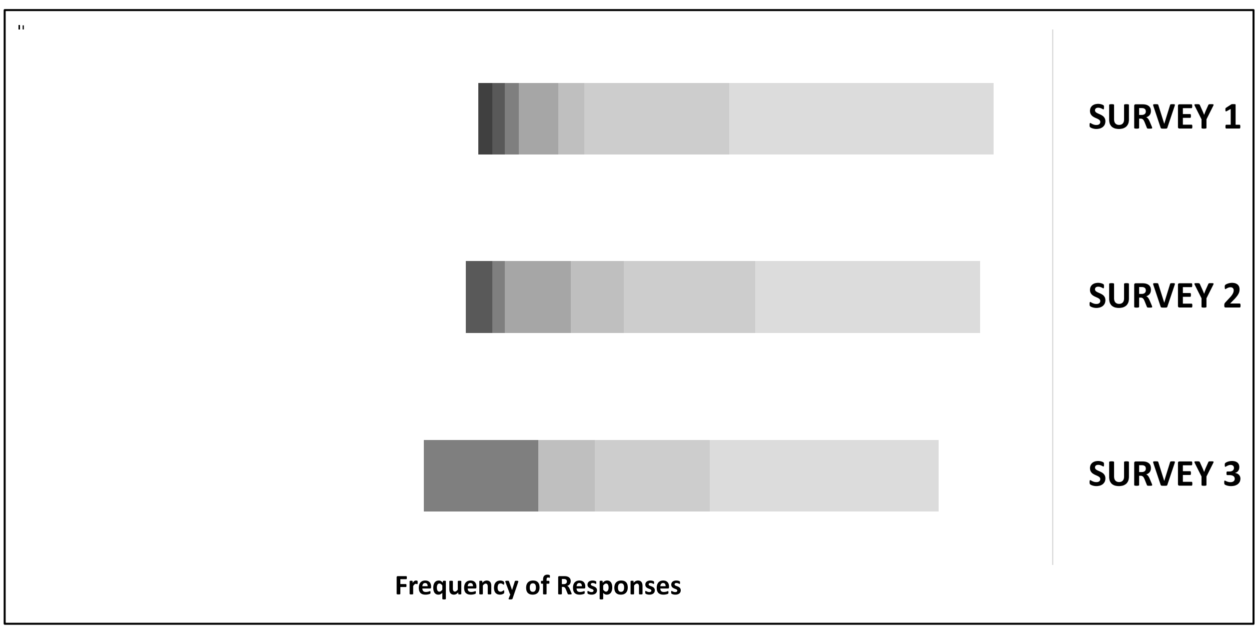


Figure 10.3 - Missed Classes Would be Harmful to My Learning (Part I) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 10.4

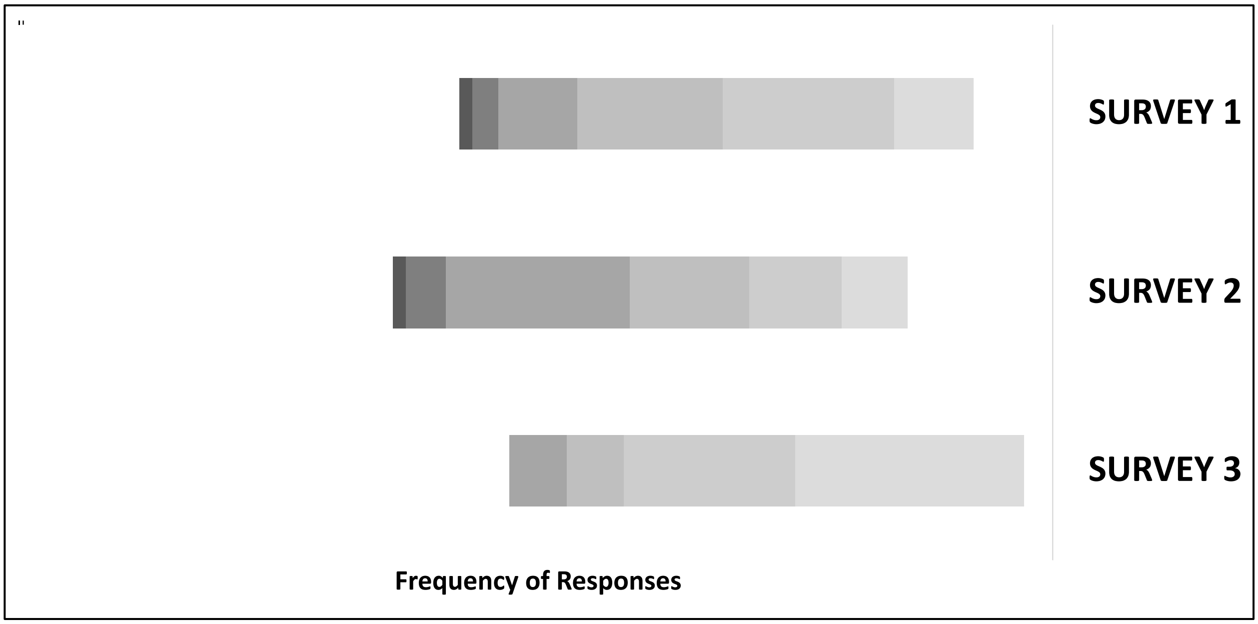


Figure 10.4 - To Memorize Equations (Part I) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 10.5

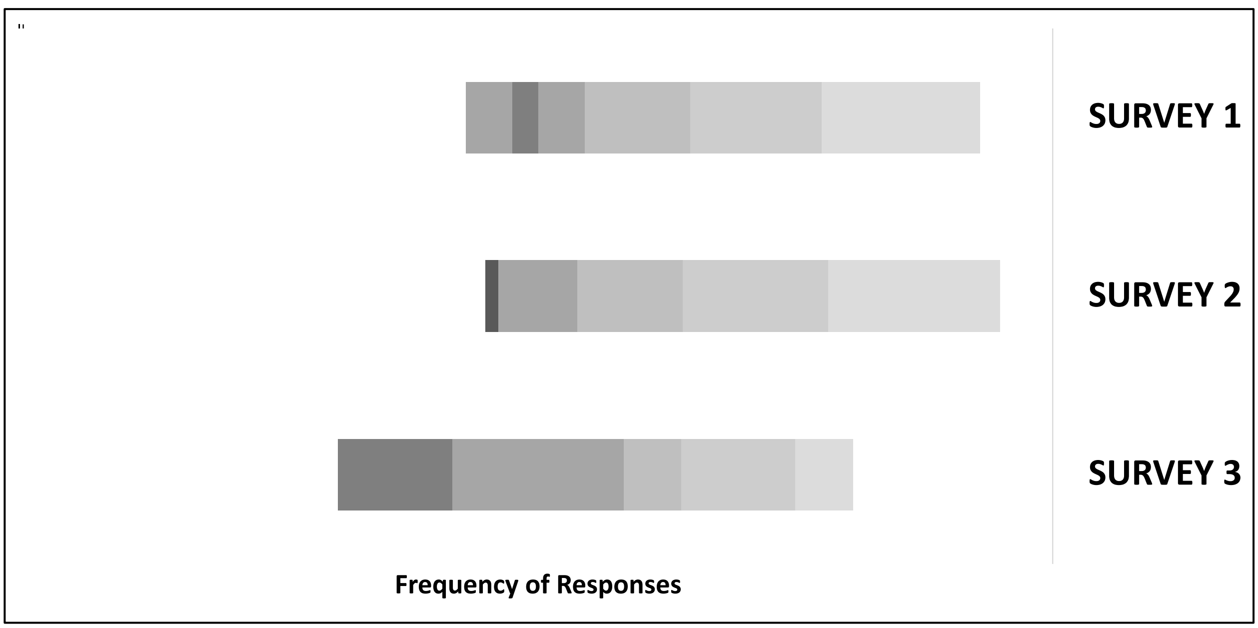


Figure 10.5 - To Interact with my Instructor during Class Time (Part I) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 11.0

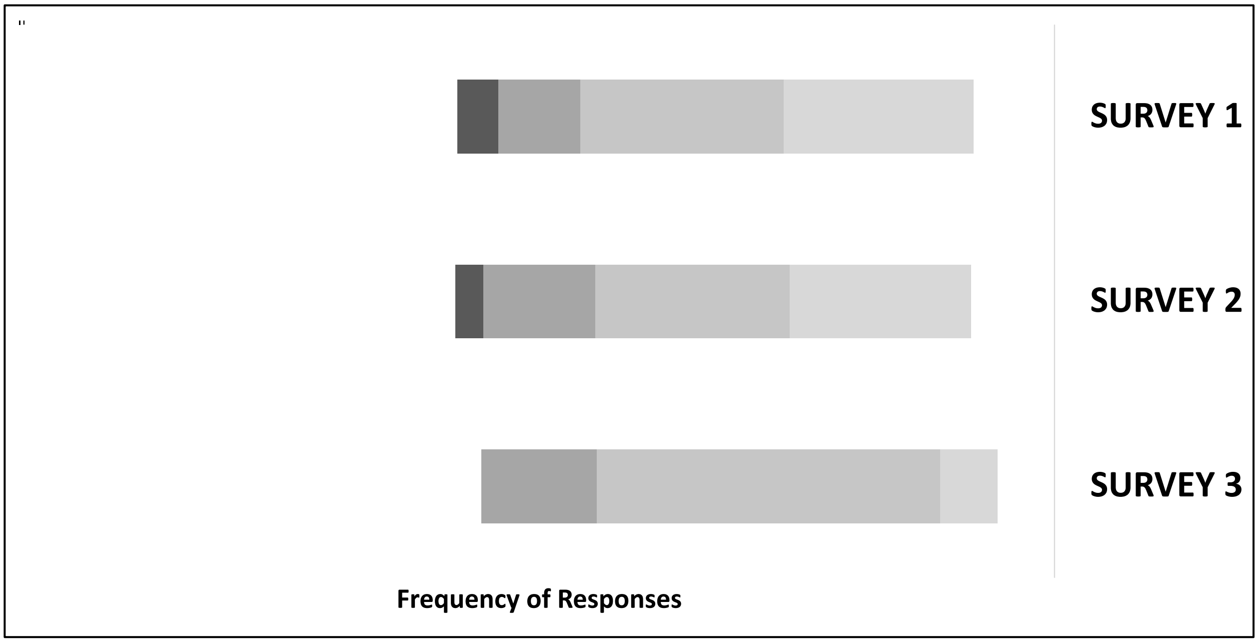


Figure 11.0 – I Feel Confident Applying my Math Skills to Chemistry (Part II) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 11.1

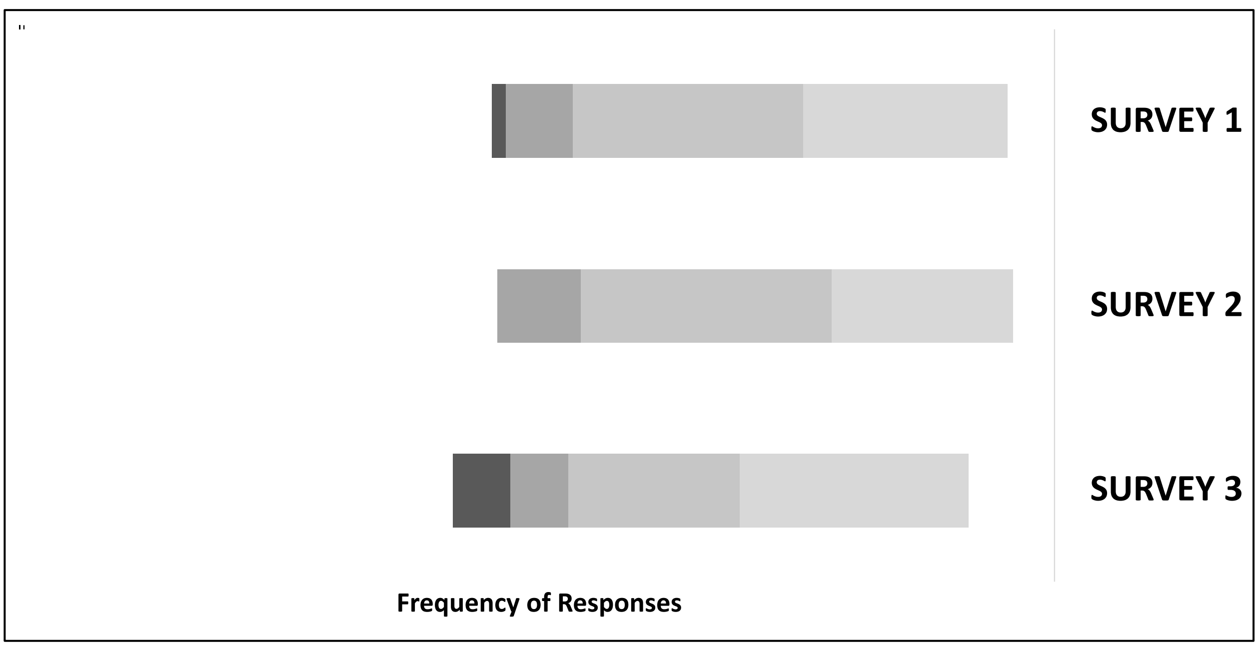


Figure 11.1 – I Feel that I Have Sufficient Math to Succeed in this Course (Part II) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 11.2

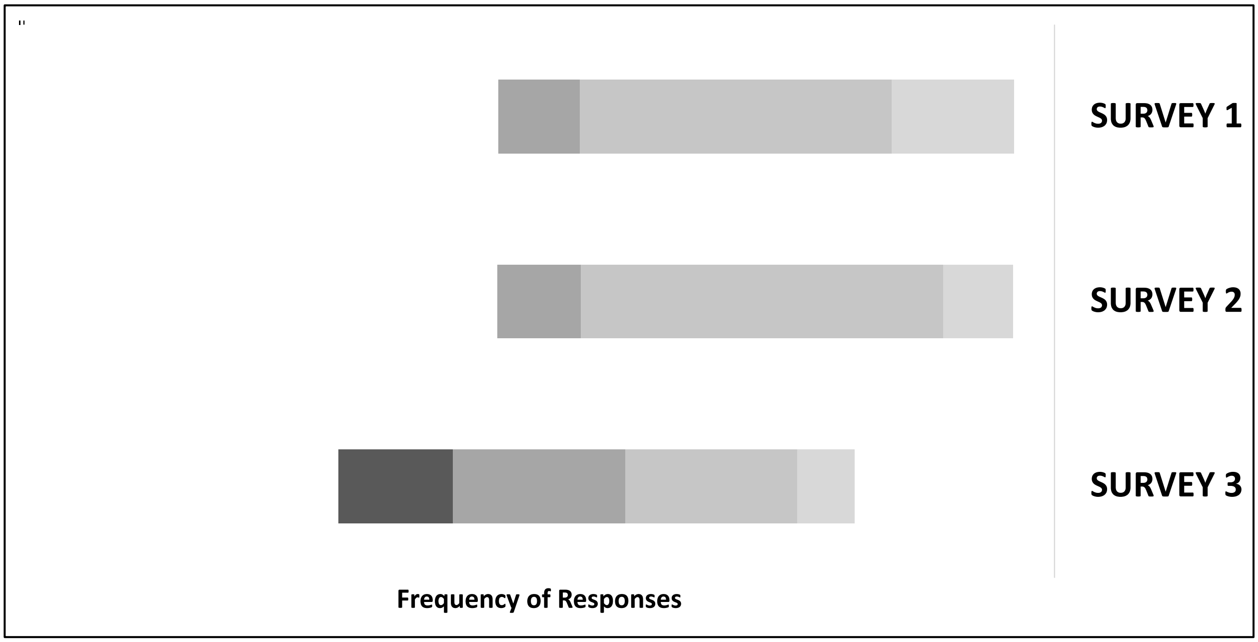


Figure 11.2 – I Think that I Should Review Concepts from Previous Math Courses (Part II) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 11.3

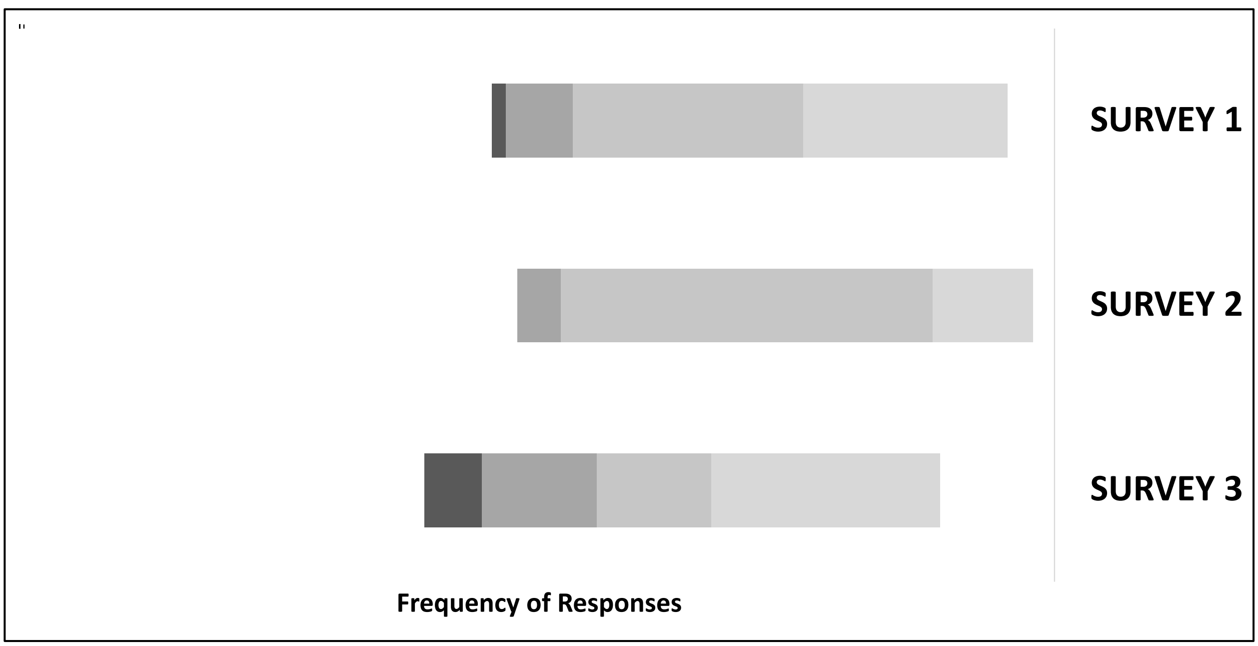


Figure 11.3 – I Think that I Should Review Concepts from Previous Chemistry Courses (Part II) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 11.4

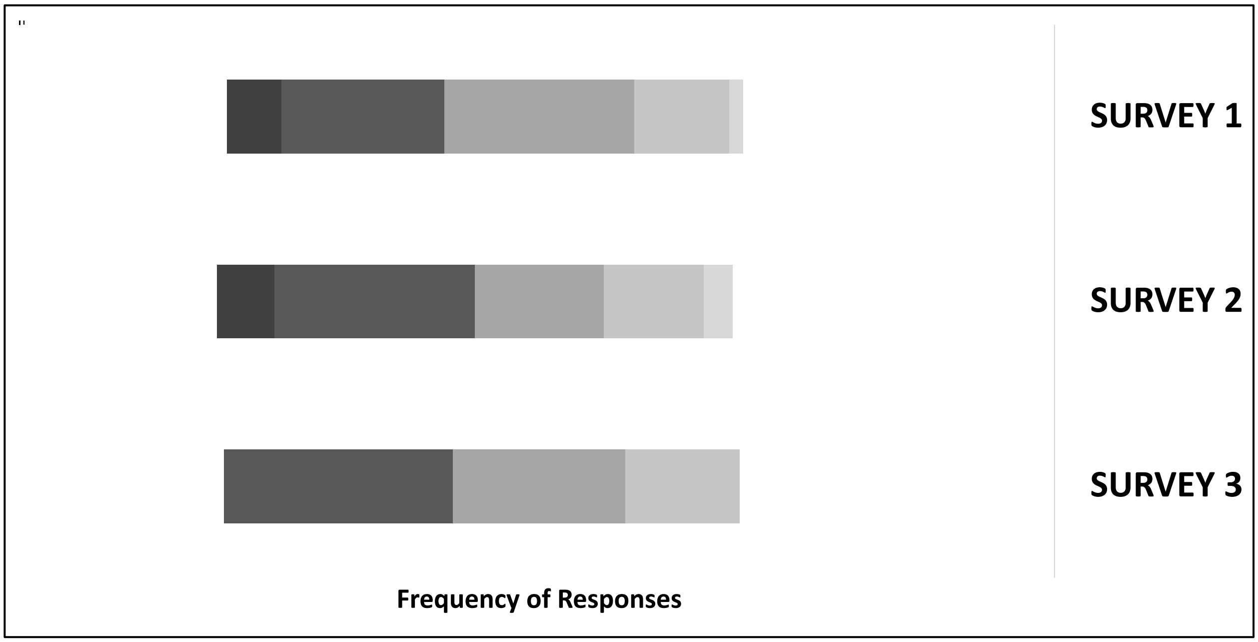


Figure 11.4 – I Think this Class will have too Much Math in it (Part II) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 11.5

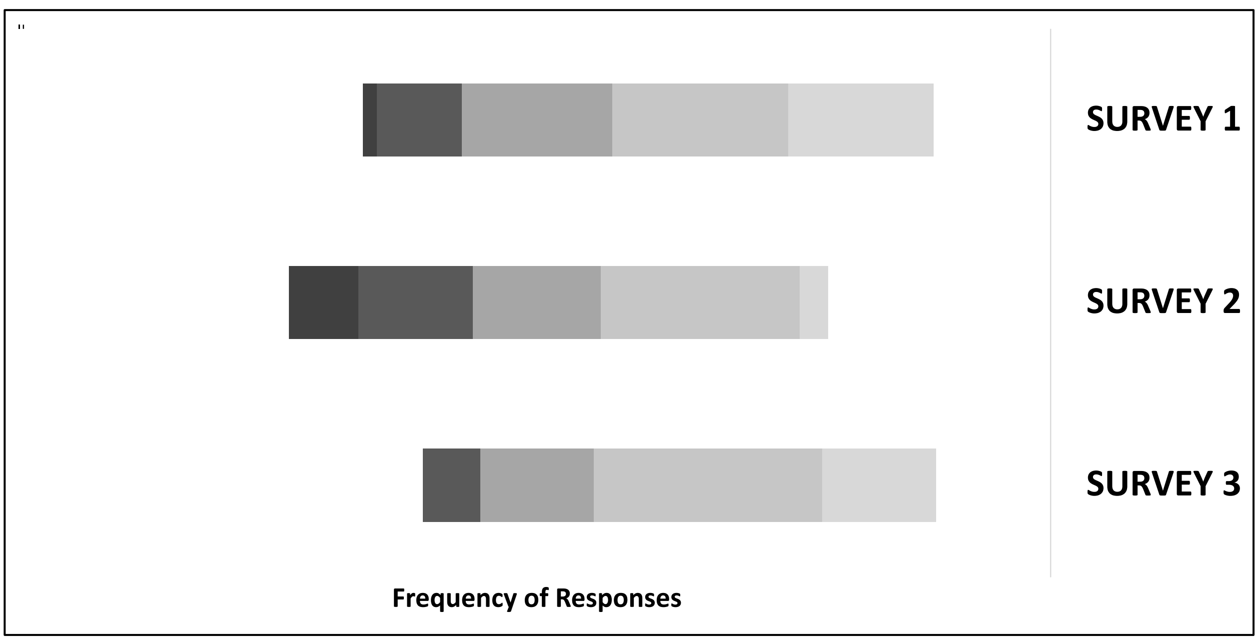


Figure 11.5 – I am Only Taking this Course Because it is Required (Part II) Responses ***(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 11.6

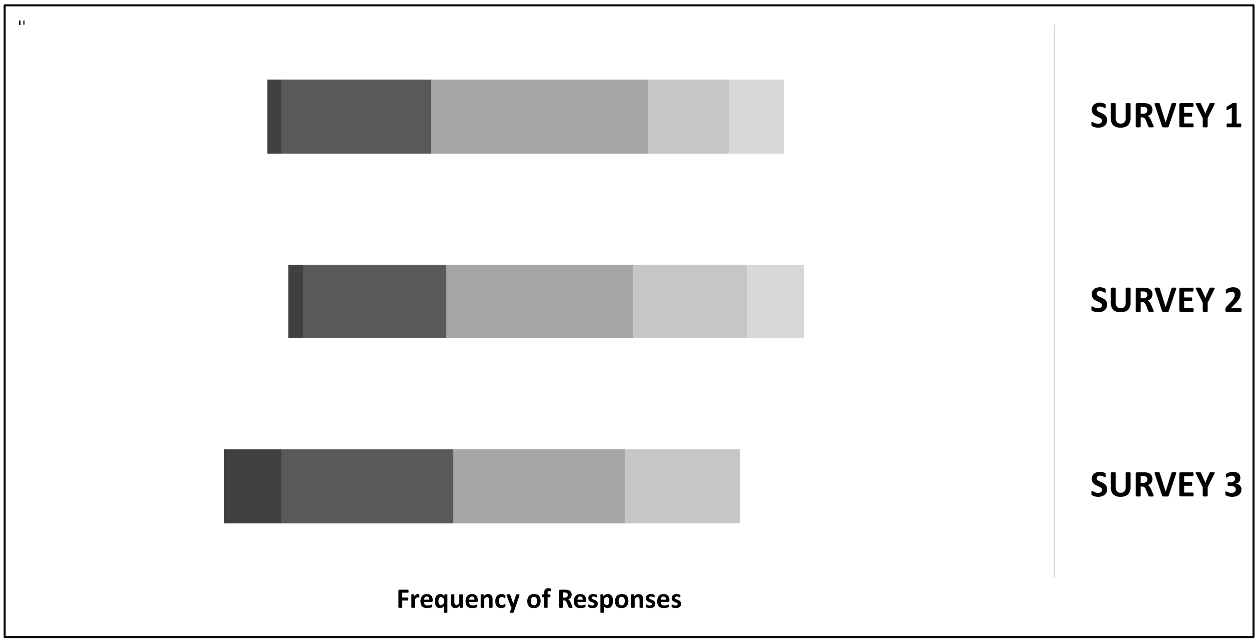


*Figure 11.6 - The Grade I Receive in this Course is Less Important than What I Learn (Part II) Responses **(S1: n=39, S2: n=39, S3: n=9)***

FIGURE 12.0

Figure 12.0 – Legend (Survey Questions Part I)

FIGURE 13.0

Figure 13.0 – Legend (Survey Questions Part II)

TABLE 2.0

Surverys (Part I) Significant Statements	Prototypical Patterns
Lecture	-
A Grading Curve	-
Collaborative (Group) Discussions*	**Failure (Increasing Expectancy)**
Computer Modeling and/or Programming*	**Undershooting (Increasing Expectancy)**
Doing Required Reading	-
Missed Classes Would be Harmful to my Learning	-
To Memorize Equations	-
To Interact with my Instructor during Class Time	-
To Interact with my LA during Class Time*	**Failure (Increasing Expectancy)**
To Interact with my Peers during Class Time*	**Failure (Increasing Expectancy)**
To Explain my Work to the Class*	**Failure (Increasing Expectancy)**
To Discuss my Work with Classmates during Class Time*	**Failure (Increasing Expectancy)**
To Discuss my Work with my Instructor or LA during Class Time*	**Failure (Increasing Expectancy)**

Table 2.0 Survey 1-2 (Part I) Significant Statements (p-value <0.05) & Prototypical Patterns*

TABLE 3.0

Surverys (Part II) Significant Statements	Prototypical Patterns
I feel confident applying my math skills to chemistry.	-
I feel that I have sufficient math to succeed in this course.	-
I look forward to the math problems in this chemistry course.*	**Undershooting (Increasing Expectancy)**
I think that I should review concepts from previous math courses.	-
I think that I should review concepts from previous chemistry courses.	-
I think this class will have too much math in it.	-
I feel comfortable seeking help from others to clarify difficult material for me.*	**Failure (Increasing Expectancy)**
I feel comfortable explaining how I solve chemical problems to others.*	**Undershooting (Increasing Expectancy)**
I feel that the amount of math in this course could lower my grade.*	**Failure (Increasing Expectancy)**
I enjoy the challenges.*	**Failure (Increasing Expectancy)**
I am only taking this course because it is required.	-
The grade I receive in this course is less important than what I learn.	-
I expect to learn a lot in this course.*	**Success (Increasing Expectancy)**

Table 3.0 Survey 1-2 (Part II) Significant Statements (p-value <0.05) & Prototypical Patterns*

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