Championing the Involvement of Practitioners in the Biochemistry Educational Research Process: A Phenomenological View of the Early Stages of Collaborative Action Research

Christopher A. Nix[1], Isadore Nottolini[1], Jonathan D. Caranto[1], Yulia Gerasimova[1], Dmitry Kolpashchikov[1] & Erin K. H. Saitta[1]

[1] Department of Chemistry, University of Central Florida, Orlando, United States

Correspondence: Erin K. H. Saitta, Department of Chemistry, University of Central Florida, Orlando, F.L., United States. E-mail: erin.saitta@ucf.edu

Received: November 28, 2022 Accepted: December 22, 2022 Online Published: December 23, 2022

doi:10.5430/ijhe.v11n6p114 URL: https://doi.org/10.5430/ijhe.v11n6p114

Abstract

The disparity between post-secondary STEM instruction and the practices suggested in education and cognitive research is not a novel issue. Despite evidence-based practices being available to practitioners, traditional lecture-based instruction continues to dominate higher STEM education. In this study, we discussed practitioner involvement in biochemistry education research as a potential means to address the gap between research and practice. We used phenomenology as a lens through which to view faculty experiences of participating in a team-based curricular redesign. We administered a concept inventory to examine undergraduate students' understanding of key concepts and to identify misconceptions. We captured faculty perspectives and reflections on student data through semi-structured interviews, finding that faculty dissatisfaction with traditional practices were rooted in experiences from early on in their teaching careers. Their students demonstrated a lack of conceptual understanding, similar to findings of other studies in undergraduate biochemistry, and key misconceptions the student population held were identified. When examining students' conceptual understanding data, the faculty gained new insights into where students struggle in the course that they would not have gained without participation in this project. This reinforced their desire to implement curricular change. These findings add to the available data on students' conceptual understanding in biochemistry and suggest that shared assessments like concept inventories can unify instructors as they engage in team-based curricular reform.

Keywords: Biochemistry education, collaborative action research, descriptive phenomenology, concept inventory, faculty experiences

1. Introduction

Over decades of chemistry education research (CER), evidence-based practices have been developed and implemented to enhance the quality of instruction and improve student performance. By evidence-based practices, we mean practices reported in the literature that benefit student learning and/or success (Eddy, Converse, & Wenderoth, 2015; Teo, Goh, & Yeo, 2014). Many of these practices focus on having students take an active role in the learning process, which has been shown to increase student performance over traditional passive learning formats (Freeman et al., 2014). Furthermore, these practices have had an even greater impact on underrepresented groups' performance and retention in science (STEM) majors (Odom et al., 2021; Theobald et al., 2020; Toven-Lindsey, Levis-Fitzgerald, Barber, & Hasson, 2015).

Examples of evidence-based practices in higher education chemistry include peer-led team learning and process-oriented guided inquiry learning, both of which promote active engagement of group learners, yet differ in the manner in which the discussion is connected (Gosser & Gosser, 2001; Moog, Spencer, & Straumanis, 2006). These active learning methods have received notable recognition from the CER community for introductory chemistry courses (Cooper & Stowe, 2018; Franziska K. Lang & Bodner, 2020; Teo et al., 2014). Additionally, these methods have been used to improve upper-level chemistry courses such as biochemistry and physical chemistry courses (Gosser & Gosser, 2001; Loertscher, Villafañe, Lewis, & Minderhout, 2014; Platt, Roth, & Kampmeierc, 2008). Research in biochemistry education has examined additional interventions such as "worked examples plus practice" and "productive failure," which have had a promising impact on student performance (Halmo et al., 2020).

However, despite the overwhelming number of studies that demonstrate their effectiveness, these practices are not as widely adopted as the traditional lecture-based courses that still dominate undergraduate STEM education (El-Adawy, Huynh, Kustusch, & Sayre, 2022; Henderson & Dancy, 2007; Stains et al., 2018). Investigations into why lectures have prevailed suggest that a likely culprit has been a lack of consideration of how evidence-based practices can be adapted to fit the teaching settings of each instructor (Henderson & Dancy, 2007). A case study on faculty participation in online communities of practice suggests that practitioners can misunderstand how literature describes the way practices could be best implemented (El-Adawy et al., 2022). Furthermore, a broad examination of STEM education has found that despite faculty interest in departing from lecture-based learning, faculty often struggles with barriers in these practices' implementation (Sansom, 2019). Research has also shown that a faculty's value of and perceived ease of implementation influence their adoption of a new practice (McCourt et al., 2017). Additional research has indicated that faculty members often rely on personal experiences to inform their teaching practices over evidence presented within the literature (Andrews & Lemons, 2015). This observation may relate to faculty's struggles with understanding the available literature (El-Adawy et al., 2022).

Recently, efforts have been made to address this disparity in chemistry education between research and practice through a series of professional development workshops (Macaluso et al., 2021). In an after-workshop survey, participants self-reported an increased understanding of evidence-based practices (Macaluso et al., 2021). However, it remains uncertain whether these efforts alone will be sufficient and whether more research is needed to understand how to support faculty's implementation of and persistence in using evidence-based practices.

The disparity in research and practice is not restricted to STEM instruction but is an issue in education as a whole (Borg, 2009; Vanderlinde & van Braak, 2010). In the field of English language teaching, Borg (2009) surveyed 505 English teachers (both at a university and non-university level) from across 13 countries and found that the majority of practitioners lacked the necessary time or understanding to read or engage in research in their fields. Similarly, Vanderlinde and van Braak (2010) found practitioners to be concerned with the practicality of research-based practices and struggling with the technical language of the education literature. In their view, so long as the practitioner's role in the educational research process is solely to apply evidence-based practices, this disconnect between research and practice will continue to prevail (Vanderlinde & van Braak, 2010). Instead, researchers are encouraged to increase the involvement of practitioners in educational research so that they can gain both the skills necessary to use evidence-based practices as well as an appreciation for their value. Leach and Tucker (2018) arrived at a similar conclusion in their study on the gap between research and practice in clinical nursing, and they advocated for greater practitioner involvement in the research process.

Since these works, a number of studies have explored active approaches to introducing practices to faculty (Corrales, Goldberg, Price, & Turpen, 2020; Dancy, Lau, Rundquist, & Henderson, 2019; El-Adawy et al., 2022; Pelletreau et al., 2018). These studies, though they differed to a degree in their methodologies, largely focused on faculty communities of practice as a tool for professional development (Corrales et al., 2020; Dancy et al., 2019; El-Adawy et al., 2022; Pelletreau et al., 2018). These studies also shared similar conclusions: faculty members working together to explore and implement practices suggested by the literature tend to sustain their efforts and grow in their appreciation for educational research (Corrales et al., 2020; Dancy et al., 2019; El-Adawy et al., 2022).

A model of research that fits the implications these studies made and the communities they explored is action research. Action research is a framework that involves practitioners examining the current needs of their courses and selecting methods they feel best address those needs (Efron & Ravid, 2019; Norton, 2009). This form of research is not restricted to practitioners managing their inquiry alone; rather, it can be a collaborative process involving other practitioners and researchers within the field (Bishop-Clark & Dietz-Uhler, 2012). Although action research is an umbrella term for a variety of research, it is based on the foundational concept of moving from observing the state of the course, through considering how to address any existing issues, to taking action (Stringer & Aragón, 2020).

Action research can be conducted in any field of study. In their recent review of biochemistry education research, Lang and Bodner (2020) described the benefits of adopting action-based research practices. Specifically, they articulated the value of practitioners' understanding of how interventions can be better applied to specific student groups rather than their universal application of an intervention (Franziska K. Lang & Bodner, 2020). Biochemistry is a unique upper-level chemistry class that requires students to bring together knowledge from multiple prerequisite courses. Moreover, a considerable amount of research has been conducted to implement evidence-based practices for beginning general chemistry courses, but researchers have not observed an impact of these practices on student performance in biochemistry (Scott E. Lewis, 2014; Teo et al., 2014). Although providing a strong foundation in any discipline is certainly important, an excessive focus on earlier courses does little to benefit students in upper-level courses (Scott E. Lewis, 2014). Hence, further research is needed to understand and support faculty efforts in implementing evidence-based practices in upper-level courses.

A frequent tactic employed within action research has been self-reflection on the outcomes of an intervention by participating researchers (Leitch & Day, 2000; Magee, Bramble, & Stanley, 2020). These reflection experiences and opportunities to make choices in the research process are a predominant feature of the early and late phases of collaborative action research in particular (Magee et al., 2020). Within the context of biochemistry, thus far, these particular reflections have only been examined though surveys in the published literature (Loertscher et al., 2014). Though research on biochemistry faculty experiences in action research has been quite limited, a study published as part of a PhD dissertation examined the general experiences and beliefs of faculty teaching biochemistry via a hermeneutic analysis of faculty interviews (Franziska K Lang, 2018). This paper seeks to add to the literature by providing a closer look at faculty experiences and perceptions of students' conceptual understanding.

In this paper, we will (1) present the research questions as well as the methodological and theoretical frameworks; (2) describe the quantitative and qualitative research methods; (3) provide descriptions and interpretations of faculty reflections and student performance; and (4) discuss conclusions, limitations, and suggestions for further research.

1.1 Research Questions

The goal of this study is to explore biochemistry faculty experiences while participating in a collaborative action-based curricular redesign as a first step towards closing the gap between research and practice. This includes soliciting faculty members' instructional experiences as well as their perspectives of students' conceptual understanding and the interplay between the two. This paper reports findings from the beginning stages of a larger study and aims to answer the following questions.

- What experiences have shaped the way faculty approach teaching biochemistry?
- How does faculty conceptualize student performance in the early stages of curricular redesign?

2. Methods

2.1 Methodological and Theoretical Framework

For this project, we used a phenomenology framework because it focuses on the "lived experiences," "life world," or phenomena of a targeted community to provide insights into the challenges the population faces and the choices it makes to address such challenges (Østergaard, Dahlin, & Hugo, 2008; Wojnar & Swanson, 2007). Unlike methodologies such as ethnography and protocol analysis, phenomenology traditionally does not rely on frameworks existing within the community to analyze experiences; rather, phenomenological studies typically rely on inductive coding (Starks & Brown Trinidad, 2007). This study used descriptive phenomenology, which focuses on describing the core structure of a phenomenon while limiting the bias the researcher holds (Husserl, 1970; Wojnar & Swanson, 2007). While phenomenology often focuses on the collective experiences of the group associated with a given study, differences in experiences were not wholly ignored in our analysis to truly express the experiences of participants (Cibangu & Hepworth, 2016; Hasselgren & Beach, 1997).

We noted that descriptive phenomenology is a distinct philosophical stance from the interpretative phenomenology Heidegger proposed, which seeks to interpret the meaning in experiences that may not be clear to participants themselves (Lopez & Willis, 2004). These distinct flavors of phenomenology also act as theoretical frameworks within the larger methodological framework of phenomenology (Lopez & Willis, 2004).

CER researchers have noted the benefits of this methodology as a means to better understand why researchers observe particular results in their quantitative inquiries (Burrows, Ouellet, Joji, & Man, 2021). For example, phenomenological analysis has been used to highlight the experiences of pre-service teachers and describe the impact of a prep course on participants' instructional choices (Kirbulut & Bektas, 2011).

One concern that needs to be addressed when applying descriptive phenomenology in the context of this study is how phenomenology can be paired with action research without conflicting with the other's philosophical assumptions. The effort to avoid such clashes in philosophical underpinning is particularly challenging when considering the broadness of action research in terms of the epistemological stances that prior researchers have assumed (Cassell & Johnson, 2006). To simplify this process, we focused on the form of action research we employed in reference to our cooperative work with the faculty. This cooperative inquiry within action research positions its researchers and its participants (in this case the faculty) not as disconnected entities but as a unit that cohesively participates in the research process (Magee et al., 2020). This particular flavor of action research entails exploring the positions of the involved participants after an initial examination of the problem they wish to address as well as the experiences of the participants after action has occurred (Magee et al., 2020). These key phases in the process are moments that the adoption of phenomenology as a research tool can aid. Ladkin (2005) suggested that phenomenology can help action researchers understand their own subjectivity and take a step back to appreciate the "other" involved in the process.

3. Population and Instructional Context

The research took place in the southeastern United States at a university with high research activity. Three biochemistry faculty members, authors JC, YG, and DK, requested collaboration with CER authors ES, CN, and IN to investigate the process of curricular redesign in the biochemistry sequence. The participating faculty had a diverse range of teaching experiences. Table 1 details the participants' characteristics. All three faculty members were research active with ~60% of responsibility for research (focused on biochemistry) and ~30% for teaching. The remaining percentage of the faculty's responsibilities were related to administration.

Table 1. Characteristics of participating faculty during participation

Faculty	Position	Course Section	Years Teaching Biochemistry
Instructor 1	Tenured	Biochemistry I	13 years
Instructor 2	Tenure track	Biochemistry I	5 years
Instructor 3	Tenure track	Honors Biochemistry I	1 year

The investigation took place in the Biochemistry I course for science majors in Fall 2019. Student data were collected in two large lecture sections and one smaller honors section of Biochemistry I where all sections covered the chemical structure, reactivity, and functions for the four main classes of biological compounds: carbohydrates, nucleic acids, proteins, and lipids. The two large sections (instructor 1, n = 269: instructor 2, n = 284) as well as the honors section (instructor 3, n = 23) were taught in a face-to-face format over a 16-week semester. The honors course had the same curriculum as the large lecture sections but a smaller class environment. Instructor 1 held classes twice weekly (Tuesdays and Thursdays) for 90 minutes each, whereas Instructors 2 and 3 held classes 3 times a week (Monday, Wednesday, Friday) for 50 minutes each class.

The undergraduate biochemistry sequence, as the setting for this collaborative action research, has a unique place among the upper-level courses offered by a department of chemistry. Unlike other upper-level chemistry courses, which have a student body comprised almost entirely of chemistry majors, biochemistry courses typically consist of predominantly non-chemistry majors (of which health and biomedical science majors make up the majority). Furthermore, Biochemistry I is often the last chemistry course most health and biological majors require, resulting in a rather large student roster compared to other upper-level courses in chemistry. Given the large lecture setting of the Biochemistry I course, probing individual student outcomes to determine areas for improvement can be a challenge. Additionally, any intervention applied in the course will need to be adaptable to a large class size.

This study shared both the quantitative and qualitative approaches of the early phase of the research. The quantitative data were intended to provide the motivation and context for the qualitative portion of the analysis, the faculty reflections and conceptualization of student performance, which was the primary focus of the paper. Figure 1 shows how this investigation fits into the larger overall project, which was informed by the cyclic process that action research entails. This study will focus on the first two steps of the project, with an emphasis on faculty interviews.

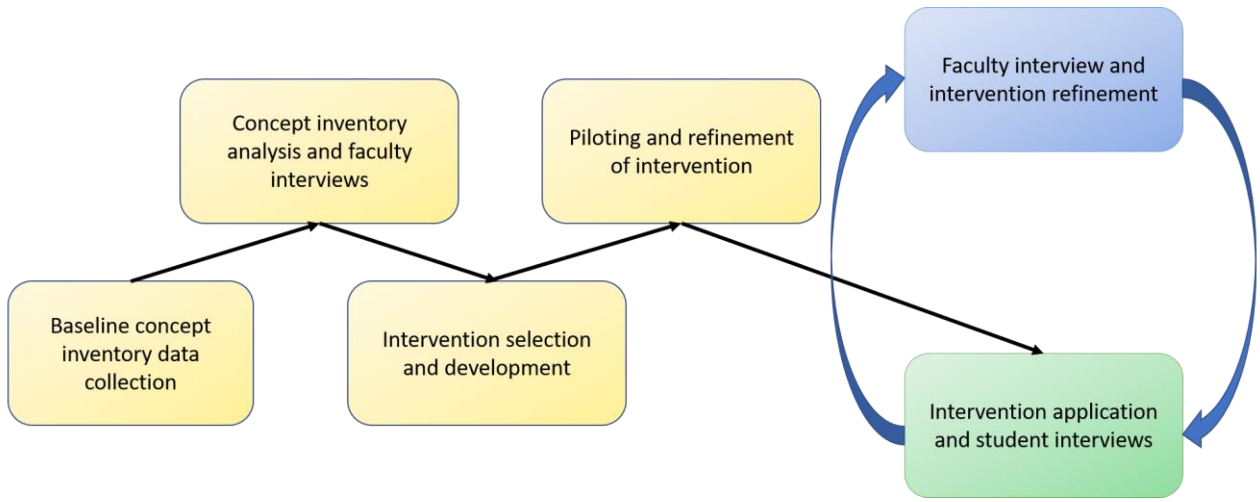

Figure 1. Diagram showing the different phases of the larger action research project

4. Data Collection and Instrumentation

4.1 Quantitative Instrument

The instrument of foundational concepts in biochemistry (IFCB) was chosen to probe students' key conceptual understandings of biochemistry. Villafañe et al. (2011) developed this instrument as a 24-item multiple choice assessment to observe a student's understanding of eight prerequisite concepts deemed critical to success in biochemistry. The faculty selected four concepts from the modified version of the IFCB (hydrogen bonding; alpha helices; pK_a; and Gibb's energy, which was referred to as thermodynamics by the faculty), which they thought were critical for students' success in their biochemistry courses (Xu, Lewis, Loertscher, Minderhout, & Tienson, 2017). Three questions, which were uniquely formatted to not be repetitious, covered each concept (Sachel M. Villafañe et al., 2011). The distractors for a given question were based on preidentified misconceptions students held and were consistent among the related questions. If a student answered all three related questions correctly, they were identified as having understanding of a concept. Subsequently, answering any one question incorrectly for a concept categorized a student as not understanding a concept. Students were identified as having a misconception if they selected the same distractor for all three related questions.

This instrument was chosen because it had undergone rigorous validation and reliability checks. In both the modified and unmodified variants, confirmatory factor analysis was employed to check the internal structure (Sachel M. Villafañe et al., 2011; Xu et al., 2017). Cronbach's alpha was calculated for each concept in the IFCB, in which only pK_a was not consistently above the threshold value of 0.7 (Xu et al., 2017). Further, the IFCB is easy to administer and provides multiple avenues of analysis in terms of both the data itself and its psychometrics. The faculty selected the instrument because it covers topics that the faculty agreed were critical to understanding the course content. They also found it useful that the instrument uses distractors as a means to probe for misconceptions in the students' conceptual understanding. Although remediating such misconceptions would not ensure a genuine understanding of the concepts, leaving such conceptions unaddressed, if present, would not benefit the students and could serve as the starting place for an intervention.

4.2 Student Sampling

The sampling frame (n = 553 large lecture, n = 23 honors) for this study consisted of the undergraduate students taking the two large sections and one honors section of Biochemistry I for science majors. Students were provided two opportunities to consent to participation via an online consent request sent through Qualtrics and a consent form attached to the post-test. There were 316 students in the large class, and 16 students in the honors class took both the pre-test and post-test and provided their consent. A misprint on the exam for one of the large lecture sections resulted in a question needing to be thrown out, resulting in a reduced sample of 150 student answers available for the hydrogen bonding concept items. Descriptive categorization of the data was performed on the entire consenting population. Inferential statistics was conducted with a subsample of 164 students who were randomly selected from this sample set via the Statistical Package for the Social Sciences (SPSS), which is used in tests of associations.

4.3 Interviews

In the interest of understanding the experiences and perspectives of the instructors before making any curricular changes, the three faculty members participated in semi-structured interviews. They were interviewed in their own offices to reduce the stress and anxiety that can be associated with the interview process (Elwood & Martin, 2000). To further increase their comfort, the faculty had their choice of interviewer: the first author, a CER graduate student, or the corresponding author, a CER faculty member. The corresponding author was chosen to conduct each interview. The interviews were 30 minutes each in duration and were held the semester immediately following the student data collection. They were audio recorded via a Sony handheld recorder.

The interviews consisted of three segments. The beginning questions prompted faculty reflection on their perspectives and experiences of teaching biochemistry. Next, the faculty were asked how well they believed their students understood the target concepts. The IFCB pre- and post-test data from students in their individual courses were then provided to the faculty to view for the first time. The last part of the interview asked faculty to respond to student data and provide their perspectives. Faculty members were asked to share their ideas on possible interventions to address student learning. Table 2 shows example questions from the interview protocol (see Appendix B for the full interview protocol).

Table 2. Example faculty interview questions

Question Type	Question Example
Before data reveal question	What experiences have shaped the way you design your class?
After data reveal question	How does this information compare to your understanding of student performance in biochemistry?

4.4 IFCB Score Analysis

Student IFCB scores were processed initially in Excel to categorize the respective learning levels of correct concepts and misconceptions (i.e., Were the misconceptions retained, lost, or acquired during the semester?) (Figures 2 and 5, respectively). The inferential statistics were conducted in SPSS and R.

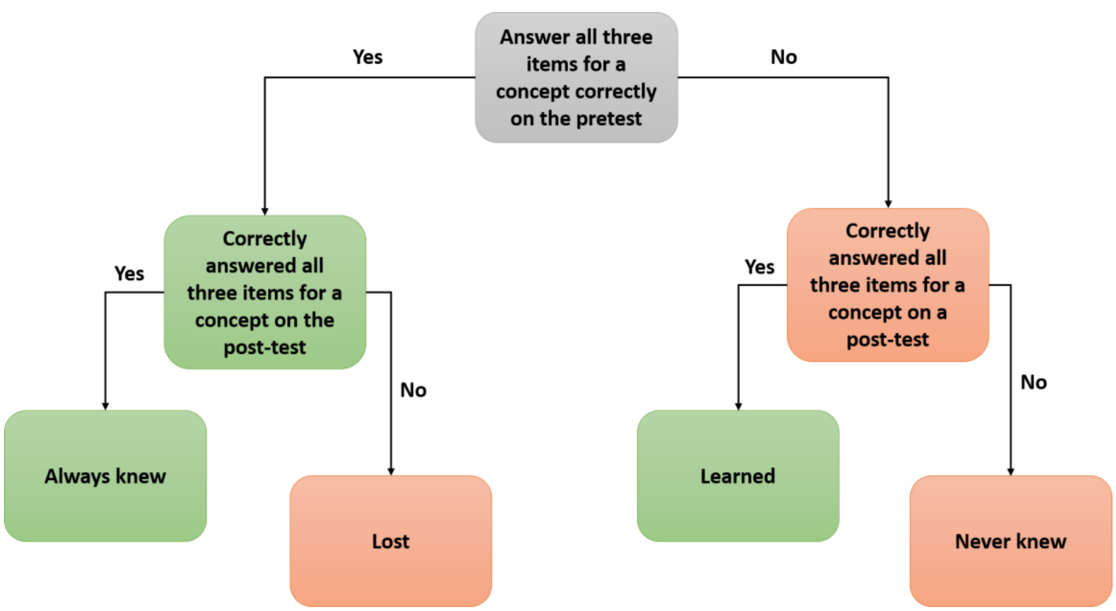

Figure 2. Flow chart showing how IFCB data were categorized into the different learning levels

Chi-squared test of association

IFCB data revealed that when students displayed at least one misconception at the end of the course, the concept was most likely hydrogen bonding and/or alpha helix. We conducted further analysis to determine whether the number of students with a particular misconception was tied to a specific instructor to obtain insight into how instruction may or may not perpetuate alternative understandings. To accomplish this, we used SPSS to generate a random subsample from which we could conduct a chi-squared test of association. This test was conducted only on misconceptions about the alpha helix concept because hydrogen bonding data were not available for both classes (as described in the methods section).

4.5 Interview Analysis

Transcription

Interviews were transcribed using Otter.ai transcription services. Author CN reviewed these rough transcripts to correct transcription errors and returned them to the faculty to further check their quality. The faculty were given an opportunity to elaborate more about a given interview topic if they believed that there was more to be noted about the topic (Sanders, 2003). The transcripts were then arranged into four spreadsheets in Excel (one spreadsheet for each primary interview question) to group different excerpts from each interview together for further analysis.

Analytical framework

We selected a modified version of Colaizzi's seven-step analytical framework (Figure 3) to analyze the faculty interviews and answer our research questions. Qualitative researchers in nursing and other medical fields frequently use this framework to guide analysis of data collected in phenomenological studies (Sanders, 2003). The appeal of this particular analytical framework over other frameworks used in phenomenology is its systematic nature and ease of use (Sanders, 2003).

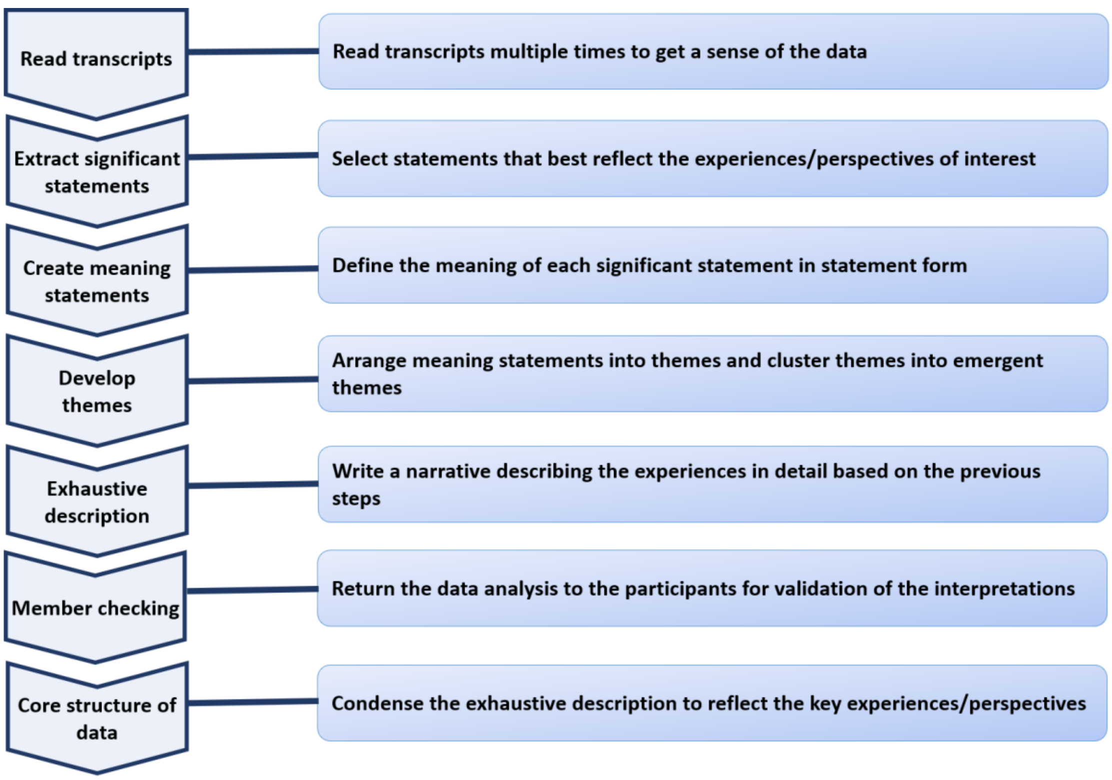

Figure 3. Modified Colaizzi's seven-step analytical framework

Although Colaizzi (1978) returned the core structure of the phenomenon to the participants, Sanders (2003) suggested that the exhaustive description should be returned to the participants instead because it would be more recognizable to the participants. We took this suggestion a step further by returning the description to the participants before we defined the core structure of the faculty experiences and perspectives. We believed this arrangement did not betray the goals of this framework and reduced the amount of backtracking should the faculty point out any inconsistencies in the analysis.

Unit of analysis

The units of dialog used in the analysis of the transcripts were statements conveying a particular point the authors deemed to be a meaningful expression of the faculty's experiences. These statements typically consisted of 1 to 3 sentences (though rarely beyond 1) within the transcript that conveyed a particular point. These statements then had their meanings defined and clustered into themes as the analytical framework directed (Colaizzi, 1978). This process is an inductive method of analyzing data and is consistent with the philosophical assertions of phenomenology.

Establishing trustworthiness

We kept audit trails for each stage of the analysis, which we returned to the participants for confirmation of their accuracy (Colaizzi, 1978). To ensure the transparency of the analysis, the first author kept a journal describing the choices made during the analysis and reflecting on the rationale for these choices (Appendix C). Authors CN, IN, and ES identified significant statements individually and then went through each statement together to choose by consensus which ones would be used in the analysis.

5. Results and Discussion

The results of the analysis included student data that provided context for faculty action research as well as faculty reflections and conceptualizations of student performance.

Students' Conceptual Understandings

The majority of students lacked sufficient understanding of the target foundational concepts.

The data were categorized into the learning levels identified by the IFCB. A large proportion of students displayed gaps in knowledge of foundational concepts on both the pre- and post-tests. As Figure 4 shows, more than 50% of students never knew each concept sufficiently enough to consistently answer the three questions on that concept correctly. Furthermore, nearly 14% of students "lost" their understanding of alpha helices, as evidenced by students answering all three questions correctly on the pre-test while having inconsistencies on the post-test. In the case of hydrogen bonding, 86% of students lacked sufficient understanding (having lost their understanding or never knowing enough to answer the three questions correctly) by the end of the course. Xu et al. (2017) obtained similar findings in which a large section of students struggled with hydrogen bonding. However, our student population had a larger proportion of students in the "never knew" category and a smaller proportion in the "lost" category.

The honors students, as Figure 4 shows, had a greater proportion of students who "always knew" the foundational concepts compared to the large lecture sections. Additionally, the honor students finished the semester with the greatest mastery of thermodynamics and pK_a (whether through always knowing or learning) compared to the students in the large sections, with a less who "never knew." However, the honors students also struggled with hydrogen bonding, with 13% of the students scoring in the loss of understanding category and 63% of students scoring in the "never knew" category at the end of the semester. This observation between students in large sections and honors sections has not been reported in previous works.

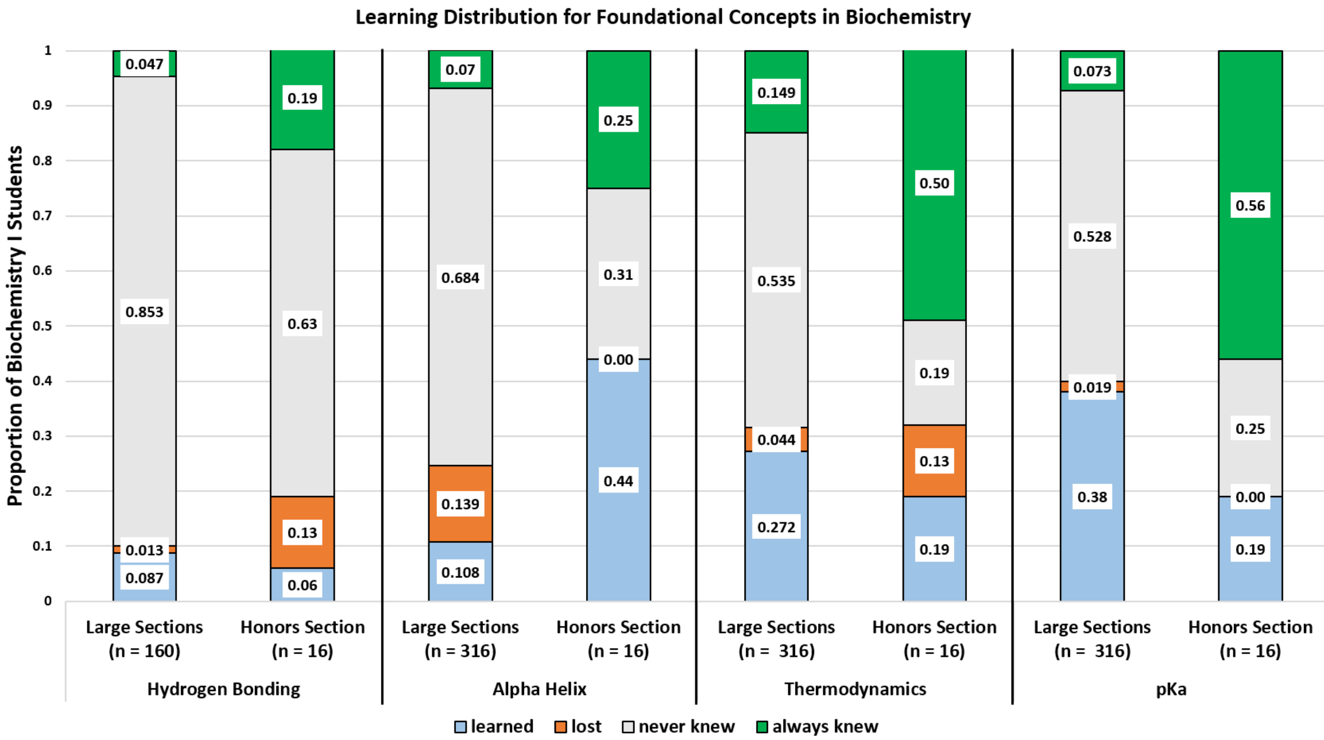

Figure 4. Learning level distributions for the four target concepts from the IFCB

The IFCB identified prevalent misconceptions.

To better understand the misconceptions the IFCB measured, we analyzed students' selection of matching distractors (see Appendix A for the misconception categorization scheme). By doing so, we could see the types of misconceptions students held and how these misconceptions (or lack thereof) were involved in students' learning levels. This information was presented to the faculty members during their interviews so that they could see the range of student performance in their class.

		Misconception	% Biochemistry Students	% Honor Biochemistry Students
Hydrogen bonding	1	Hydrogens bonded to carbons can participate in hydrogen bonding	36.2%	50%
	2	Any bonding between hydrogen and another atom is a hydrogen bond	11.8%	6.2%
Alpha helices	1	The interior of the helix is composed of side chain groups (R groups)	19.3%	31.2%
	3	Molecules such as water fill the interior of the alpha helix	6.3%	0%

Figure 5. IFCB's commonly identified misconceptions within the student sample

Although a few students displayed misconceptions about thermodynamics and pK_a, the majority of student misconceptions were about hydrogen bonding and/or alpha helices. IFCB data revealed that ~25.6% of large section and 31.2% of honors section students held misconceptions about alpha helices at the end of the course. Additionally, ~67.9% and ~40% of these students respectively demonstrated misconceptions on the post-test and not the pre-test (implying that the misconceptions were formed the same semester they took the biochemistry class). Specifically, the major misconception students held was misconception 1 (Figure 5), which represented ~19% of the large lecture students and ~31% of the honors students at the end of the course.

The other target foundational concept with a large number of student misconceptions was hydrogen bonding, a concept addressed in multiple chemistry and biology courses, which are a prerequisite for the biochemistry course. A total of ~48% of large section and ~56% of honors section students held a hydrogen bonding misconception at the end of the course. From this data set, ~71% and ~67% of students respectively gained the misconception during the semester. Further, ~73% of large lecture students and ~88% of honors students identified as having a misconception consistently chose distractors tied to hydrogen bonding misconception 1. More details on the misconception data can be found in Appendix A. The predominance of hydrogen bonding misconception 1 is consistent with the data reported within the literature (Kopecki-Fjetland & Steffenson, 2021; Xu et al., 2017). Prior work has also noted that the alpha helix misconception 1 was the most common misconception present among the sampled participants (Sachel M Villafañe, Loertscher, Minderhout, & Lewis, 2011).

Misconceptions present among the students were independent of instructors

Because of the high percentage of students whose IFCB data indicated they experienced misconceptions during the course, additional analysis was conducted on the data sets to determine the extent to which the frequency of misconceptions was related to a specific section of the class, which all had different instructors, times of day, and class activities. Table 3 displays the results of a chi-square test of association between the misconceptions the large section students held about alpha helices at the end of the course and the instructor of the specific section (see Appendix A for the contingency table used for the test). The chi-squared test of association produced a p-value that was greater than the conventional alpha value ($p = 0.154 > \alpha = 0.05$), suggesting a lack of association between the misconception data and the instructors of the course. The assumptions for this test were not met because the expected count was less than 5 for two categories (Table A.9). Thus, Fisher's exact test was conducted, yielding similar results with a p-value of 0.150. This further suggested a lack of association between the instructor's section and the misconceptions students held at the end of the course.

Table 3. Statistical outputs for test of association between alpha helix misconceptions and instructor

Statistic	Value
Chi-squared p-value	0.154
Cramer's V	0.151
Fisher's exact test p-value	0.150
Post hoc power	0.39
Priori power sample size	423

The effect size was calculated via SPSS ($w = 0.151$, Cramer's V), which was small based on the conventional interpretation of that value (Ellis, 2010). Furthermore, post hoc analysis yielded a statistical power of 0.39, and priori power analysis suggested that a sample size of 423 would be required to observe a significant association among the tested variables. Given the low power and high sample size required, a larger sample size is unlikely to provide a valid statistical association between instruction and student misconceptions. This analysis was useful for the collaborative faculty action research because it contextualized the struggle students experience mastering the content of the course as independent of the instructor. This knowledge allows the faculty to see the struggle points in students' understanding as a group challenge rather than as the burden of one particular faculty member.

5.1 Faculty Experiences and Perspectives on Teaching

We analyzed transcripts from faculty interviews where faculty discussed biochemistry education, and we reflected on student data. We identified 12 unique themes, which we condensed into five emergent themes. The theme data (Figure 6) was not the endpoint of the analysis. Rather, the themes acted as building blocks, which we used to construct an exhaustive description of the data and, later, the core structure of the faculty teaching experiences

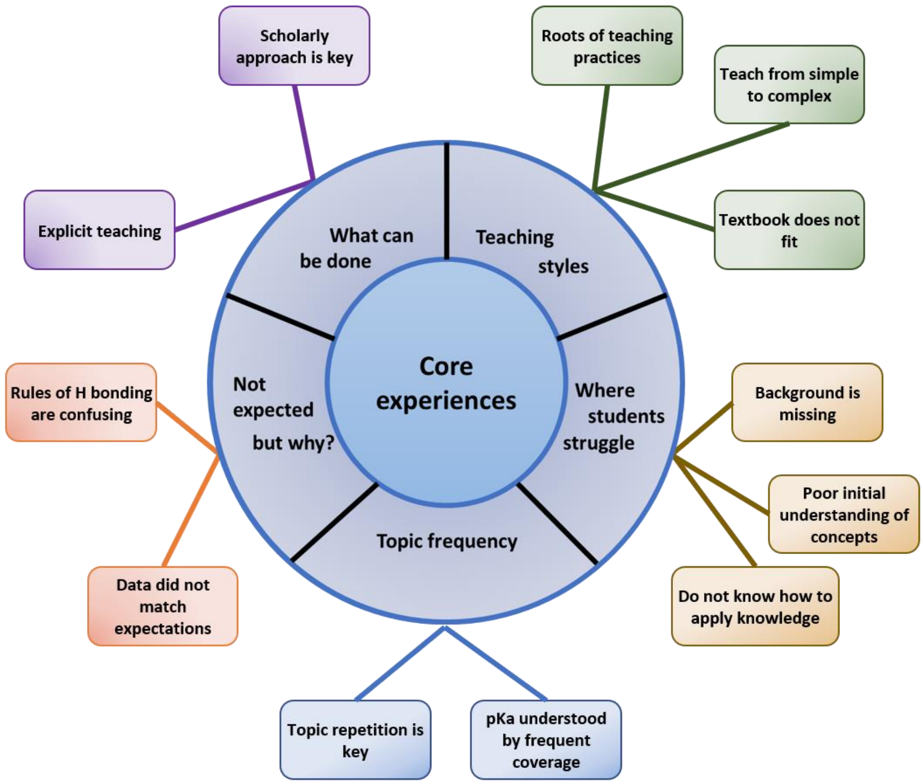

Figure 6. Theme data construct of the core structure of faculty experiences

Faculty members wanted to improve instruction, but past experiences influenced their choice of focus.

Regarding teaching styles, faculty shared the desire to alter the way the biochemistry content was presented. Much of the motivation for this shift from traditional approaches was derived from faculty's previous teaching experiences (notably from early within their career) or experiences as students. The nature of these experiences also shaped how faculty members felt about their current teaching deviating from what they considered to be traditional instruction. For one participant, their previous job as a tutor motivated them to focus on problem-solving as a way to gauge students' content knowledge. The faculty member noted that this experience as a tutor had the greatest impact on their teaching style. They found that by accessing students' understanding with multiple low-risk assessments, they could identify struggle points to address in a class discussion.

Instructor 3: "*So most of most of my teaching philosophy derives from my work as a tutor . . . So I'm more of a troubleshooter than a lecturer.*"

Another participant's experience as a teaching assistant drove them to be dissatisfied with the order in which content was presented in the course. This led them to rearrange the content so that simple molecules were introduced first. From there, they moved on to more complex systems to emphasize the chemical perspective of biological systems. The faculty member felt that by starting with content that was more familiar to students and building up from there, students would have an easier time understanding the content.

Instructor 1: "*From the very beginning, I had my take on how to teach it. When I arrived, I immediately decided to teach it from chemical perspective. So, using all the background that students [were] supposed to have collected or accumulated during their undergraduate education.*"

Instructor 1: "*And from this background moving towards understanding more complex biological objects.*"

Instructor 2 adopted this approach early in their teaching career, as shown below, after an unofficial peer-to-peer conversation with instructor 1 prior to their involvement in the action research.

Instructor 2: *"I've had some experience like, for example, from Instructor 1, right, because instructor 1 was teaching it and we kind of communicated [as] to how they decided to schedule their class.*" (Changed pronouns to maintain confidence of instructor 1)

Instructor 2: "*So in this case, and I think it's beneficial, to first start with introducing the molecular um, um, like building blocks for each biopolymer, right.*"

An issue that the two participants encountered upon implementing this new curricular layout was the textbook assigned to the course. The faculty members observed a disconnect between how the text and the course content were arranged and the difficulties the students had in connecting the two. Therefore, the faculty sought to create a new textbook for the course that would align with the curriculum.

Instructor 1: "*That's why at the end of the first semesters, I got an idea to write in our own text, which is more concise and focused on concepts that I want to teach to students.*"

Instructor 2: *"So, again, because the traditional textbooks use a traditional approach of introducing the material, I had to kind of jump from section to section, and students usually feel like a little bit lost.*"

Before seeing the baseline data, faculty perceived an overall lack of student background knowledge.

When considering how students struggled with the course content, faculty member shared their frustration with the state of students' background knowledge. Two faculty members expressed their feeling that students typically lacked sufficient understanding of prerequisite course content. One faculty member noted that the lack of background knowledge in students was not an isolated view but one their supplemental instructor (an undergraduate who displayed excellent understanding of the course content and facilitated help sessions for students) shared as well. The two faculty members attributed this lack of prior knowledge to students' poor understanding in earlier courses. One faculty member felt that students abandoned knowledge that they did not perceive to be relevant to the next assessment (quiz or test) rather than understand and retain that knowledge.

Instructor 1: "*I would say more than 50% of students struggle with insufficient background knowledge that is required for biochemistry.*"

Instructor 2: "*They don't view biochemistry as that easy subject because it kind of builds up on their prior chemistry knowledge. Yes. All what they were lacking from general chemistry, organic chemistry classes, like either abandoned or didn't get, you know, out of these classes.*"

While reading the exhaustive description of the interview data, instructor 3, who taught the honors section, hesitated to claim that the students altogether lacked understanding of background knowledge. Rather, the faculty member thought students likely had sufficient knowledge but were unsure when to apply it.

Instructor 3: "*There's a lot of discussion about prior knowledge, and it's not clear to me that we are able to tell the difference between lack of prior knowledge and inability to understand when the prior knowledge should be applied.*"

Instructor 2 expressed a similar view when they suggested that students' difficulties with applying prior knowledge could contribute to their focus on memorization in biochemistry. The participant felt that the students did not know when to apply prior concepts towards current content, which led them to drop and no longer value prior knowledge.

Instructor 2: "*But then they don't use it, you know, they kind of memorize something right? And they don't apply it next time*."

Instructor 2: "*I don't think I included examples of this type of questions in my homework or in other course assignments. And so they just didn't think that it's important, right? And that's why it just slipped.*"

Baseline data-initiated conversations about topic frequency and student misconceptions

The faculty held some preconceptions on how students would perform, and the IFCB (the instrument they selected to examine students' conceptual understanding) either supported or challenged these preconceptions. Before and after the class data were shown to them, the faculty noted that the frequency of topic coverage influenced the number of students with positive scores. Before the class data were revealed in the interview, instructors noted that topics such as pK_a and thermodynamics were covered frequently in the course (both in the class and within office hours). The faculty believed that covering the topics more frequently throughout the course led to better retention and conceptual understanding among students. After seeing the IFCB scores, some faculty ideas were affirmed. Specifically, in the case where more students learned pK_a, the instructors felt this made sense given how frequently the topic was covered.

Instructor 3: "*Definitely go through that a million times pK_a. So yeah, yeah, we go through pre-drill that big time.*"

Instructor 1: "*Well, about pK_a. I felt like that's what was expected. Because they had they [come] to my office and we covered this multiple times because they asked about this.*"

However, the student data challenged other faculty ideas. When reflecting on the extent to which their expectations were aligned with the data, the instructors expressed a disconnect between their preconceptions of students' understanding and what the data were telling them. This disconnect was largely oriented towards what the students understood at the end of the course rather than what content knowledge the students possessed before they entered the course. The instructors had observed (via tests and conversations during office hours) that the students understood the concept of alpha helices by the end of the course. This conflicted with the IFCB student data presented to them in the interview. One instructor noted that they had not expected students to have had any prior knowledge on alpha helices and was shocked by the proportion of the lost category for the concept:

Instructor 2: "*Surprisingly alpha helix that I felt they know so well. They don't know. Or they learned incorrectly from, from my instruction. And that's a shocking thing.*"

Instructor 1: *"Well, first of all, alpha helix, my expectation was, they didn't know anything about alpha helix because they didn't have to [interviewer: learn it in prior courses]. It was a new concept taught in biochemistry and as you can see, there is a significant loss [interviewer: of knowledge] instead of gain.*"

Making sense of student misconceptions was another shared experience where instructors reflected on what was happening and why in their courses. One instructor noted that students may be confusing alpha helices with DNA double helices, in which the backbone constitutes the exterior while the nucleotide base pairs (which differentiates the nucleotides as R groups differentiate amino acids) constitutes the interior of the double helix. This instructor also believed that what they described as the "tricky" nature of hydrogen bonding could easily confuse students:

Instructor 3: "*What's interesting is I wonder if they're getting confused with the interior of the interface of two helices instead of thinking about the interior of the core.*"

Instructor 3: *"The hydrogen bonding. Yeah, I could see that. That's a tough one. I think . . . I think it's tricky because there's so many rules.*"

Baseline data provide the context for decisions on a curricular intervention.

Finally, the instructors shared their perspectives on what could be done to address the gaps in students' understanding. Two of the faculty members mentioned a need to be more explicit about the details of the target concepts. In addition to being more explicit, one faculty member noted that including more application prompts would promote the students to value prior knowledge. The instructor felt that, currently, students did not know that they needed to apply this knowledge and hence did not see the value of maintaining a working memory of it. One faculty member stressed the importance of approaching the changes to the curriculum in a systematic way to improve the rigor of an intervention. The instructor was enthusiastic about using creative exercises, open-ended activities that required students to provide statements about a given prompt, as a tool to target the weaknesses in students' understandings of key concepts (Scott E Lewis, Shaw, & Freeman, 2010; Trigwell & Sleet, 1990).

Instructor 3: "*But yeah, I don't explicitly discuss packing on there. Maybe I should.*"

Instructor 2: "*And I also think that um more um questions for the applications are needed, you know, to kind of force them to apply because that's definitely they are not applying the knowledge even if they have the knowledge.*"

Instructor 1: "*Our plan was to interfere, right [interviewer: Mm hmm] and do it in a systematic way [interviewer: Mm hmm]. I just think that we should follow our plan.*"

5.2 Core Structure Insights

This phenomenological study captured the lived experiences of this faculty group and gave insights into the challenges the biochemistry faculty faced before the curricular redesign. The results implied that there may be a prevalence of uncertainty among faculty as to how they can alter their curriculum in a way that is beneficial to the students. Previous attempts to make changes to the curriculum that did not noticeably yield the desired results may bolster these feelings of uncertainty. This could be seen in the faculty's efforts to change the order of materials and yet feel unsatisfied with student performance. This feeling was not unique to participants in the current study; Lang et al. (2018) examined a range of biochemistry faculty experiences, finding that faculty believed existing materials on evidence-based practices did not provide sufficient guidance to implement them effectively.

Another insight from this study was how intertwined the faculty recollections of their teaching experiences were with their perceptions of students' understanding. This was particularly true for the more experienced faculty members who frequently brought up student background knowledge when discussing their experiences. We can see from the core structure of the faculty members' experiences that this interplay between their experiences of teaching and conceptualization of students' understanding contributed to their current teaching practices. Furthermore, the faculty members' concerns about the lack of students' understanding, despite their own efforts to address the situation, may have motivated them to seek collaboration with experts in educational research. This interest to collaborate was reflected in a prior study in which a surveyed faculty group expressed the desire to obtain input from education experts during the curriculum redesign process (Loertscher et al., 2014).

6. Conclusion

Our analysis of the faculty interviews identified a set of five emerging core experiences (teaching styles, where the students struggle, topic frequency, not expected and why, and what can be done) through which we could present a narrative of the faculty experiences. Regarding the experiences that shaped the way the faculty approached teaching, we can see that their desire to move away from traditional practices was not an impromptu one. Rather, the faculty started their current careers with a determination to break away from conventional approaches based on their earlier teaching experiences. Their own experiences with education early in their professional careers drove this determination to move away from the traditional curriculum. The literature has shown that such a feature is not unique to this faculty group (Andrews & Lemons, 2015).

Another key takeaway from this data was that the IFCB provided the faculty with a fresh perspective on the conceptual understandings of their students that may have gone unnoticed otherwise. Though the faculty had unique perspectives on how to approach the curriculum, albeit ones rooted in similar goals, the instrument provided the faculty with unifying target points by which they could collaborate to address these areas of interest. The newfound common ground could be a promising avenue for faculty members to see the benefits of collaboration with one another despite overall differences in their teaching approaches. Additionally, while prior research has used the IFCB as a tool for faculty members to target concepts that could be better addressed in their courses, this is the first study to interview the faculty as they reflected on their personal data. Prior works either used a survey to elicit faculty perspectives or did not conduct substantial discussion on the matter (Loertscher et al., 2014; Sachel M Villafañe et al., 2011; Xu et al., 2017).

The faculty believed that their concerns were legitimate because student data highlighted the need to address the current biochemistry curriculum. Indeed, a desired conceptual mastery of key concepts escaped the majority of students. This situation cannot continue if undergraduate students are to truly excel in their course of study and later careers. Furthermore, a number of students were identified as having misconceptions by the end of the course, specifically for hydrogen bonding and alpha helices. A test of association suggested that this phenomenon is not unique to the section that the students participated in, further supporting the idea that a team-based approach to curricular change may prove more effective than an individual effort.

This research has benefited not only faculty members who are determined to improve the quality of their courses but also the educational researchers who collaborated on this project. By exploring the experiences and perspectives that led to the drive for curricular redesign, the researchers better understand what evidence-based practices would lead to the best improvement in student learning, and what interventions may be most compatible with the perspectives of the instructors.

6.1 Limitations

One notable limitation of this study was our ability to describe the data corresponding to the concept of hydrogen bonding. This limitation was due to the previously mentioned printing error, which led to a reduced sample size and minimized our ability to compare student performance on this concept between sections. Our sample size for the honors section was also limited, though this was largely due to the size of the course itself rather than limited participation. That said, this small sample size minimized our ability to compare the honors section with the large sections. Furthermore, given the nature of the instrument as a concept inventory composed of multiple-choice questions, the student data presented here could only provide a glimpse into the conceptual understanding of the students. The intended use of this instrument was not to gain a holistic understanding of students' conceptual knowledge, but rather to garner a general sense of knowledge related to a handful of concepts.

The instrument itself may have induced a level of bias in the faculty's perception of student performance in the course. While the data from the IFCB were generally aligned with the faculty perceptions of student foundational understanding, it was not our intention for the instrument to represent holistic learning in the overall course. Rather, we intended the instrument to bring focus to a few key areas that could be reasonably addressed in the curricular redesign. In this context, the instrument did cause the faculty to explore their preconceptions of students' conceptual understanding (i.e., that none of the students came to the course with knowledge on alpha helices).

Given the nature of action research, the generalizability of this study is limited. We did not anticipate that theses snapshots of the three faculty experiences would have broad application to other settings. Instead, we hope that by documenting these experiences and perspectives, we can encourage the field to investigate the role of practitioners in curricular redesign research. Additionally, by sharing these experiences with a broader audience, we hope to provide readers with an opportunity to consider their own experiences with teaching as well as understand how the documented experiences relate to their own experiences.

6.2 Implications and Future Research

This study is an example of how stakeholders, who are invested in widespread adoption of evidence-based practices, can prioritize the experiences and conceptions of practitioners throughout the implementation process to better understand the shared and individual qualities that influence change on a curricular level. While our findings from this study provide insights into one faculty group's experiences as they prepare to engage in curricular redesign, more work is needed to identify the transferable aspects of successful faculty team engagement in curricular change. Although this has been explored in other studies, these studies still recommend further exploration of such aspects on a broader scale (Pelletreau et al., 2018). It also highlights the importance and the need for professional development in earlier points in faculty members' careers, such a graduate teaching.

One critical remaining question relates to faculty buy-in, specifically, what experiences lead faculty towards embracing education research as a tool for improving instruction. While studies have investigated how faculty networks have influenced adoption of evidence-based practices (Dancy et al., 2019; Lane et al., 2019; Pelletreau et al., 2018), there still remains more to be explored as to why some faculty adopt evidence-based practices and others do not. These lived experiences of faculty involved in curricular decision-making demand more attention to understand this gap. Similarly, while authors have explored faculty persistence and motivation for curricular change (Corrales et al., 2020; Dancy et al., 2019; McCourt et al., 2017), more investigation of the motivations that initiate and sustain chemistry faculty participation in curricular change is needed.

References

Andrews, T. C., & Lemons, P. P. (2015). It's Personal: Biology Instructors Prioritize Personal Evidence over Empirical Evidence in Teaching Decisions. *CBE—Life Sciences Education, 14*(1). https://doi.org/10.1187/cbe.14-05-0084

Bishop-Clark, C., & Dietz-Uhler, B. (2012). *Engaging in the scholarship of teaching and learning: A guide to the process, and how to develop a project from start to finish*: Stylus Publishing, LLC.

Borg, S. (2009). English Language Teachers' Conceptions of Research. *Applied Linguistics, 30*(3), 358-388. https://doi.org/10.1093/applin/amp007

Burrows, N. L., Ouellet, J., Joji, J., & Man, J. (2021). Alternative Assessment to Lab Reports: A Phenomenology Study of Undergraduate Biochemistry Students' Perceptions of Interview Assessment. *Journal of Chemical Education, 98*(5), 1518-1528. https://doi.org/10.1021/acs.jchemed.1c00150

Cassell, C., & Johnson, P. (2006). Action research: Explaining the diversity. *Human Relations, 59*(6), 783-814. https://doi.org/10.1177/0018726706067080

Cibangu, S. K., & Hepworth, M. (2016). The uses of phenomenology and phenomenography: A critical review. *Library & Information Science Research, 38*(2), 148-160. https://doi.org/10.1016/j.lisr.2016.05.001

Colaizzi, P. F. (1978). Psychological research as the phenomenologist views it. In R. S. Valle & M. King (Eds.), *Existential-Phenomenological Alternatives for Psychology* (pp. 6): Oxford University Press.

Cooper, M. M., & Stowe, R. L. (2018). Chemistry Education Research—From Personal Empiricism to Evidence, Theory, and Informed Practice. *Chemical Reviews, 118*(12), 6053-6087. https://doi.org/10.1021/acs.chemrev.8b00020

Corrales, A., Goldberg, F., Price, E., & Turpen, C. (2020). Faculty persistence with research-based instructional strategies: a case study of participation in a faculty online learning community. *International Journal of STEM*

Education, 7(1), 21. https://doi.org/10.1186/s40594-020-00221-8

Dancy, M., Lau, A. C., Rundquist, A., & Henderson, C. (2019). Faculty online learning communities: A model for sustained teaching transformation. *Physical Review Physics Education Research, 15*(2), 020147. https://doi.org/10.1103/PhysRevPhysEducRes.15.020147

Eddy, S. L., Converse, M., & Wenderoth, M. P. (2015). PORTAAL: A Classroom Observation Tool Assessing Evidence-Based Teaching Practices for Active Learning in Large Science, Technology, Engineering, and Mathematics Classes. *CBE—Life Sciences Education, 14*(2), ar23. https://doi.org/10.1187/cbe.14-06-0095

Efron, S. E., & Ravid, R. (2019). *Action research in education: A practical guide*: Guilford Publications.

El-Adawy, S., Huynh, T., Kustusch, M. B., & Sayre, E. C. (2022). Context interactions and physics faculty's professional development: Case study. *Physical Review Physics Education Research, 18*(2), 020104. https://doi.org/10.1103/PhysRevPhysEducRes.18.020104

Ellis, P. D. (2010). *The essential guide to effect sizes: Statistical power, meta-analysis, and the interpretation of research results*: Cambridge university press. https://doi.org/10.1017/CBO9780511761676

Elwood, S. A., & Martin, D. G. (2000). "Placing" Interviews: Location and Scales of Power in Qualitative Research. *The Professional Geographer, 52*(4), 649-657. https://doi.org/10.1111/0033-0124.00253

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410-8415. https://doi.org/10.1073/pnas.1319030111

Gosser, D. K., & Gosser, D. K. (2001). *Peer-led team learning: A guidebook*: Prentice Hall Upper Saddle River, NJ.

Halmo, S. M., Sensibaugh, C. A., Reinhart, P., Stogniy, O., Fiorella, L., & Lemons, P. P. (2020). Advancing the Guidance Debate: Lessons from Educational Psychology and Implications for Biochemistry Learning. *CBE—Life Sciences Education, 19*(3), ar41. https://doi.org/10.1187/cbe.19-11-0260

Hasselgren, B., & Beach, D. (1997). Phenomenography — a "good-for-nothing brother" of phenomenology? Outline of an analysis. *Higher Education Research & Development, 16*(2), 191-202. https://doi.org/10.1080/0729436970160206

Henderson, C., & Dancy, M. H. (2007). Barriers to the use of research-based instructional strategies: The influence of both individual and situational characteristics. *Physical Review Special Topics - Physics Education Research, 3*(2), 020102. https://doi.org/10.1103/PhysRevSTPER.3.020102

Husserl, E. (1970). *The crisis of European sciences and transcendental phenomenology: An introduction to phenomenological philosophy*: Northwestern University Press.

Kirbulut, Z. D., & Bektas, O. (2011). Prospective chemistry teachers' experiences of teaching practice. *Procedia - Social and Behavioral Sciences, 15*, 3651-3655. https://doi.org/10.1016/j.sbspro.2011.04.351

Kopecki-Fjetland, M. A., & Steffenson, M. (2021). Design and implementation of active learning strategies to enhance student understanding of foundational concepts in biochemistry. *Biochemistry and Molecular Biology Education, 49*(3), 446-456. https://doi.org/10.1002/bmb.21498

Ladkin, D. (2005). 'The enigma of subjectivity':How might phenomenology help action researchers negotiate the relationship between 'self', 'other' and 'truth'? *Action Research, 3*(1), 108-126. https://doi.org/10.1177/1476750305049968

Lane, A. K., Skvoretz, J., Ziker, J. P., Couch, B. A., Earl, B., Lewis, J. E., & Stains, M. (2019). Investigating how faculty social networks and peer influence relate to knowledge and use of evidence-based teaching practices. *International Journal of STEM Education, 6*(1), 28. https://doi.org/10.1186/s40594-019-0182-3

Lang, F. K. (2018). Understanding perceptions and beliefs biochemistry instructors hold and the influence these factors have on their personal style of teaching. *Purdue University: Unpublished doctoral dissertation*.

Lang, F. K., & Bodner, G. M. (2020). A Review of Biochemistry Education Research. *Journal of Chemical Education, 97*(8), 2091-2103. https://doi.org/10.1021/acs.jchemed.9b01175

Leach, M. J., & Tucker, B. (2018). Current understandings of the research-practice gap in nursing: A mixed-methods study. *Collegian, 25*(2), 171-179. https://doi.org/10.1016/j.colegn.2017.04.008

Leitch, R., & Day, C. (2000). Action research and reflective practice: towards a holistic view. *Educational Action*

Research, 8(1), 179-193. https://doi.org/10.1080/09650790000200108

Lewis, S. E. (2014). Investigating the Longitudinal Impact of a Successful Reform in General Chemistry on Student Enrollment and Academic Performance. *Journal of Chemical Education, 91*(12), 2037-2044. https://doi.org/10.1021/ed500404q

Lewis, S. E., Shaw, J. L., & Freeman, K. A. (2010). Creative exercises in general chemistry: A student-centered assessment. *Journal of College Science Teaching, 40*(1), 48.

Loertscher, J., Villafañe, S. M., Lewis, J. E., & Minderhout, V. (2014). Probing and improving student's understanding of protein α-helix structure using targeted assessment and classroom interventions in collaboration with a faculty community of practice. *Biochemistry and Molecular Biology Education, 42*(3), 213-223. https://doi.org/10.1002/bmb.20787

Lopez, K. A., & Willis, D. G. (2004). Descriptive Versus Interpretive Phenomenology: Their Contributions to Nursing Knowledge. *Qualitative Health Research, 14*(5), 726-735. https://doi.org/10.1177/1049732304263638

Macaluso, R., Amaro-Jiménez, C., Patterson, O. K., Martinez-Cosio, M., Veerabathina, N., Clark, K., & Luken-Sutton, J. (2021). Engaging Faculty in Student Success: The Promise of Active Learning in STEM Faculty in Professional Development. *College Teaching, 69*(2), 113-119. https://doi.org/10.1080/87567555.2020.1837063

Magee, D., Bramble, M., & Stanley, D. (2020). Expanding an Action Research framework for an evidence based mentoring program in nursing: an exploration of cooperative inquiry. *Educational Action Research, 28*(4), 597-608. https://doi.org/10.1080/09650792.2019.1636695

McCourt, J. S., Andrews, T. C., Knight, J. K., Merrill, J. E., Nehm, R. H., Pelletreau, K. N.,& Lemons, P. P. (2017). What Motivates Biology Instructors to Engage and Persist in Teaching Professional Development? *CBE—Life Sciences Education, 16*(3), ar54. https://doi.org/10.1187/cbe.16-08-0241

Moog, R. S., Spencer, J. N., & Straumanis, A. R. (2006). Process-oriented guided inquiry learning: POGIL and the POGIL project. *Metropolitan Universities, 17*(4), 41-52.

Norton, L. (2009). *Action research in teaching and learning: A practical guide to conducting pedagogical research in universities*: Routledge. https://doi.org/10.4324/9780203870433

Odom, S., Boso, H., Bowling, S., Brownell, S., Cotner, S., Creech, C., & Ballen, C. J. (2021). Meta-analysis of Gender Performance Gaps in Undergraduate Natural Science Courses. *CBE—Life Sciences Education, 20*(3), ar40. https://doi.org/10.1187/cbe.20-11-0260

Østergaard, E., Dahlin, B., & Hugo, A. (2008). Doing phenomenology in science education: a research review. *Studies in Science Education, 44*(2), 93-121. https://doi.org/10.1080/03057260802264081

Pelletreau, K. N., Knight, J. K., Lemons, P. P., McCourt, J. S., Merrill, J. E., Nehm, R. H., & Smith, M. K. (2018). A Faculty Professional Development Model That Improves Student Learning, Encourages Active-Learning Instructional Practices, and Works for Faculty at Multiple Institutions. *CBE—Life Sciences Education, 17*(2), es5. https://doi.org/10.1187/cbe.17-12-0260

Platt, T., Roth, V., & Kampmeierc, J. A. (2008). Sustaining change in upper level courses: peer-led workshops in organic chemistry and biochemistry. *Chemistry Education Research and Practice, 9*(2), 144-148. https://doi.org/10.1039/B806230G

Sanders, C. (2003). Application of Colaizzi's method: Interpretation of an auditable decision trail by a novice researcher. *Contemporary Nurse, 14*(3), 292-302. https://doi.org/10.5172/conu.14.3.292

Sansom, R. L. (2019). *Understanding STEM faculty members' decisions about evidence-based instructional practices*: Brigham Young University.

Stains, M., Harshman, J., Barker, M. K., Chasteen, S. V., Cole, R., DeChenne-Peters, S. E., & Young, A. M. (2018). Anatomy of STEM teaching in North American universities. *Science, 359*(6383), 1468-1470. https://doi.org/https://doi.org/10.1126/science.aap8892

Starks, H., & Brown Trinidad, S. (2007). Choose Your Method: A Comparison of Phenomenology, Discourse Analysis, and Grounded Theory. *Qualitative Health Research, 17*(10), 1372-1380. https://doi.org/10.1177/1049732307307031

Stringer, E. T., & Aragón, A. O. (2020). *Action Research*: SAGE Publications.

Teo, T. W., Goh, M. T., & Yeo, L. W. (2014). Chemistry education research trends: 2004–2013. *Chemistry Education Research and Practice, 15*(4), 470-487. https://doi.org/10.1039/C4RP00104D

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., & Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences, 117*(12), 6476-6483. https://doi.org/10.1073/pnas.1916903117

Toven-Lindsey, B., Levis-Fitzgerald, M., Barber, P. H., & Hasson, T. (2015). Increasing Persistence in Undergraduate Science Majors: A Model for Institutional Support of Underrepresented Students. *CBE—Life Sciences Education, 14*(2), ar12. https://doi.org/10.1187/cbe.14-05-0082

Trigwell, K., & Sleet, R. (1990). IMPROVING THE RELATIONSHIP BETWEEN ASSESSMENT RESULTS AND STUDENT UNDERSTANDING. *Assessment & Evaluation in Higher Education, 15*(3), 190-197. https://doi.org/10.1080/0260293900150302

Vanderlinde, R., & van Braak, J. (2010). The gap between educational research and practice: Views of teachers, school leaders, intermediaries and researchers. *British Educational Research Journal, 36*(2), 299-316. https://doi.org/10.1080/01411920902919257

Villafañe, S. M., Bailey, C. P., Loertscher, J., Minderhout, V., & Lewis, J. E. (2011). Development and analysis of an instrument to assess student understanding of foundational concepts before biochemistry coursework*. *Biochemistry and Molecular Biology Education, 39*(2), 102-109. https://doi.org/10.1002/bmb.20464

Villafañe, S. M., Loertscher, J., Minderhout, V., & Lewis, J. E. (2011). Uncovering students' incorrect ideas about foundational concepts for biochemistry. *Chemistry Education Research and Practice, 12*(2), 210-218. https://doi.org/10.1039/C1RP90026A

Wojnar, D. M., & Swanson, K. M. (2007). Phenomenology:An Exploration. *Journal of Holistic Nursing, 25*(3), 172-180. https://doi.org/10.1177/0898010106295172

Xu, X., Lewis, J. E., Loertscher, J., Minderhout, V., & Tienson, H. L. (2017). Small Changes: Using Assessment to Direct Instructional Practices in Large-Enrollment Biochemistry Courses. *CBE—Life Sciences Education, 16*(1), ar7. https://doi.org/10.1187/cbe.16-06-0191

Appendix A

Misconception Data

Misconception Data Categorization

Table A.1.Hydrogen bonding large section student misconception categorizations (n = 143, always knew not included)

Categories	Misconception 1	Misconception 2	Misconception 3
Lost with misconception	1	0	0
Never knew learned misconception	42	12	1
Never knew retained misconception	2	4	1
Never knew lost misconception	1	5	14
Never knew swapped misconception	4	0	0
	9	3	0
Learned from misconception	0	2	0
Never knew random guessing	30		
Lost with random guessing	1		
Learned from random guessing	11		

Table A.2. Hydrogen bonding honors student misconception categorizations (n = 13, always knew not included)

Categories	Misconception 1	Misconception 2	Misconception 3
Lost with misconception	1	0	0
Never knew learned misconception	6	1	0
Never knew retained misconception	1	0	0
Learned from misconception	1	0	0
Never knew random guessing	2		
Lost with random guessing	1		
Learned from random guessing	0		

Table A.3. Alpha helix large section student misconception categorizations (n = 295, always knew not included)

Categories	Misconception 1	Misconception 2	Misconception 3
Lost with misconception	11	0	6
Never knew learned misconception	29	0	9
Never knew retained misconception	21	0	1
Never knew lost misconception	28	1	7
Never knew swapped misconception	0	0	4
	0	0	0
Learned from misconception	4	0	1
Never knew random guessing	73		
Lost with random guessing	15		
Learned from random guessing	23		

Table A.4 . Alpha helix honors student misconception categorizations (n = 12, always knew not included)

Categories	Misconception 1	Misconception 2	Misconception 3
Lost with misconception	0	0	0
Never knew learned misconception	2	0	0
Never knew retained misconception	3	0	0
Learned from misconception	2	0	1
Never knew random guessing	0		
Lost with random guessing	0		
Learned from random guessing	4		

Table A.5. Thermodynamics large section student misconception categorizations (n = 271, always knew not included)

Categories	Misconception 1	Misconception 2	Misconception 3
Lost with misconception	0	0	1
Never knew learned misconception	1	0	15
Never knew retained misconception	0	0	0
Never knew lost misconception	2	0	10
Never knew swapped misconception	0	0	0
	0	0	0
Learned from misconception	0	0	2
Never knew random guessing	141		
Lost with random guessing	13		
Learned from random guessing	84		

Table A.6. Thermodynamics honors student misconception categorizations (n = 8, always knew not included)

Categories	Misconception 1	Misconception 2	Misconception 3
Lost with misconception	0	0	0
Never knew learned misconception	0	0	0
Never knew retained misconception	0	0	0
Learned from misconception	0	0	0
Never knew random guessing	3		
Lost with random guessing	2		
Learned from random guessing	3		

Table A.7. pK_a large section student misconception categorizations (n = 295, always knew not included)

Categories	Misconception 1	Misconception 2	Misconception 3
Lost with misconception	0	0	0
Never knew learned misconception	4	3	0
Never knew retained misconception	1	1	0
Never knew lost misconception	12	4	5
Never knew swapped misconception	0	0	0
	0	0	0
Learned from misconception	1	5	2
Never knew random guessing	137		
Lost with random guessing	6		
Learned from random guessing	112		

Table A.8. pK_a honors student misconception categorizations (n = 7, always knew not included)

Categories	Misconception 1	Misconception 2	Misconception 3
Lost with misconception	0	0	0
Never knew learned misconception	0	0	0
Never knew retained misconception	0	0	0
Learned from misconception	0	0	0
Never knew random guessing	4		
Lost with random guessing	0		
Learned from random guessing	3		

Table 9. Contingency table for alpha helix post-test misconception data

	No Misconception	Misconception 1	Misconception 3
Instructor 1			
Count	57	12	5
Expected count	55	15.8	3.2*
Standardized residual	0.3	-1.0	1.0
Instructor 2			
Count	65	23	2
Expected count	67	19.2	3.8*
Standardized residual	-0.2	0.9	-0.9

Hydrogen bonding	**1. Hydrogens bonded to carbons can participate in hydrogen bonding** **2. Any bonding between hydrogen and another atom is a hydrogen bond** **3. Covalent bonds between hydrogen and other atoms are hydrogen bonds**
Alpha helices	**1. The interior of the helix is composed of side chain groups (R groups)** **2. The interior of the alpha helix is empty and the structure is not rigid** **3. Molecules such as water fill the interior of the alpha helix**
Thermodynamics	**1. A spontaneous process will always release heat** **2. A spontaneous process will proceed quickly** **3. The sign of the Gibb's energy describes whether or not the process releases heat**
pKa	**1. When the pKa of a Carboxyl group is greater than the pH, the charge is negative** **2. When the pKa of the amine group is less than the pH, the charge is positive** **3. The charge of substituents is not effected by the pH of the solution**

Figure A.1. IFCB learning levels expanded to show changes of misconceptions from pre- to post-tests

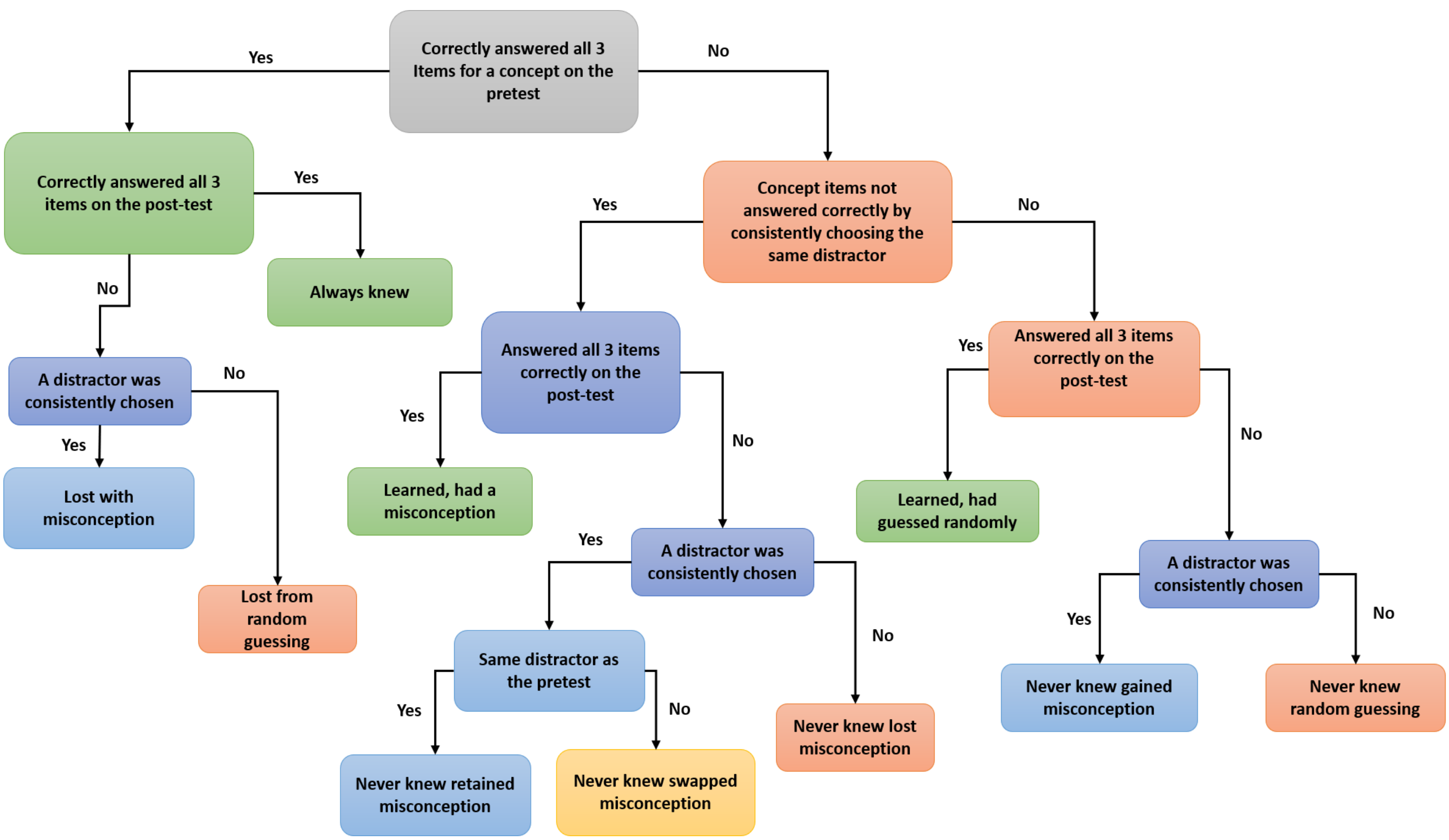

Figure A.2. Misconceptions embedded in the distractor answer choices on the IFCB concept inventory

Appendix B

Interview Protocol

Starter:

The interview will be initiated with the following statement:

So, tell me about your experiences teaching biochemistry.

Questions

What experiences have shaped the way you design your class?

What do you think biochemistry students struggle with the most?

Out of the four concepts we are assessing, which do you think the students are best at? Which are they the worst at?

Show data

After the initial interaction, prior to the interview, the participants will be presented with data depicting the performance of their students over the course of the semester.

Post-data questions

After seeing the data from the fall semester (2019), how does it compare with what you were expecting?

How does this information compare to your understanding of student performance in biochemistry?

What changes to the curriculum would you suggest based on the data?

What topics do you feel you would like to focus on the next time you teach the class?

Follow-up questions

What influenced your conception of students' performance?

How do you feel those changes to the curriculum will affect student performance?

Appendix C

Reflexivity Journal

Familiarity with the Subjects

Having taken the biochemistry course sequence at the same institution where the faculty members are employed, I have had a fair bit of insight into the way the instructors have arranged their curriculum. The exception is one faculty member who the university hired after I had received my bachelor's degree and proceeded to graduate school.

Why did I choose Colaizzi's Seven-step Method?

I chose this method for two main reasons: this method was the first one introduced to me for phenomenological research, and the idea of a systematic analysis appealed to me. I am a novice when it comes to just about any research method, and thus a more straightforward analysis plan seemed ideal for a first project. While theoretical frameworks can be convenient for the appropriate methodology, it can be rather difficult to find the right one. Such frameworks are considered inappropriate for phenomenology (because the purpose of this method is to let the data speak for itself).

Software Tools/Post-transcription Processing

For this analysis, I had the undergraduate research assistant move the transcripts from a word document to an Excel file. The transcripts were broken up into different spreadsheets based on the major questions asked in the interview. Thus, the related transcriptions for each participant were present on the same spreadsheet for ease of viewing. I also had the associated dialog (sometimes in reduced form) included in the spreadsheet in case it was needed to understand the context of the participant dialog. The participant dialog was bolded to distinguish it from the interviewer's dialog (which was italicized).

Colaizzi's Method: Step 1

For this part of the analysis framework, I read through the transcripts a few times to try and obtain a sense of the transcripts (as they say in the framework). Additionally, I had the undergraduate working on this project read the transcripts and do some free coding as well as take notes on what he found to be interesting within the data. I also went through his coding and included more notes on the data, which I highlighted in dark blue.

Colaizzi's Method: Step 2

To accomplish this section of the analysis framework, I went about reading the transcripts and extracting statements I felt were significant into a new column of the spreadsheet. I gauged the significance of the statements based on how they related to the direct question from the interviewer as well as the clarity by which the statement represented their experience. The initial coding was also useful for this process because I already had an idea of which statements were significant.

That said, I was worried that my personal experiences and biases would influence the statements. Therefore, I had the undergraduate research assistant and principal investigator determine the significant statements as well. Afterwards, we came together and compared our statements to develop an agreed set of statements. With this course of action, I hoped that having not one but three researchers decide on which statements were significant would limit (but never truly remove) the influences of personal bias on the data analysis.

Furthermore, as a group, we discussed why we chose certain statements as significant based on what we were looking for in the data. The undergraduate research assistant noted that a key feature he was looking for from a significant statement was its relevance to the preceding question. The principal investigator chose statements based on what she felt captured the big picture of the faculty experiences. We decided which statements were genuinely significant based on whether they were answering our research questions or just our own inquisitiveness.

Colaizzi's Method: Step 3

From the significant statement selection, I went about defining the meanings for each statement. For this process, I would read the statement and then look at the passage to get its context. Then, I would write what I found the statement to mean while rereading the statement and passage to make sure that the meaning statement made sense.

Colaizzi's Method: Step 4

For this step, I had the undergraduate research assistant look at the meaning statements and then highlight them in different colors depending on how similar they were to one another. From there, I placed the colored statements in a new spreadsheet based on matching colors for each column. Next, I wrote descriptive headers for each column, which would be the themes identified from the data. These themes were arranged within another spreadsheet, in which the themes were clustered into overarching emergent themes. These major themes contained two to three subthemes that the undergraduate research assistant identified. During the last stage, I noticed that some of the statements fit other themes more than the current theme. Therefore, I moved these statements into the appropriate columns without changing their colors so that the original assignment could be seen.

Colaizzi's Method: Step 5

To create an exhaustive description of what was seen in the data thus far, I transcribed the analysis as a narrative of the experiences/perspectives shared in the data. This was of course at the advice of the guide for Colaizzi's method that I was originally introduced to almost a year before conducting the current study. I initially felt that this step was a few steps backwards in terms of processing the data. However, as I went about writing the description, I started to see a few elements present in the data that I had not considered in the prior analysis steps. Furthermore, as the guide for this method suggested, the format of the narrative would be more familiar to the participants for the member checking step.

Colaizzi's Method: Step 6

The exhaustive description data were returned to the faculty. The faculty members were prompted to answer two questions to reflect on the accuracy and holistic nature of this description of their experiences (Colaizzi, 1978). Two of the faculty members stated that the description was an accurate account of their experiences and perspectives. However, instructor 3 noted that the exhaustive description did not accurately depict their perspective of students' understanding of background knowledge. The instructor noted that they believed the students indeed possessed the necessary background knowledge for the course, but the issue lay in students' uncertainty about how to use such knowledge. I was ecstatic to receive this feedback because I felt that we did not receive much input from faculty members on this topic. However, I did not go back and change the description directly; instead, I felt it would be more appropriate to address this in the core structure of the experiences.

Colaizzi's Method: Step 7

I racked my brain for ideas on how to condense the description of the data into a publishable format. The description was relatively short because of the number of participants, so it was difficult to decide how to condense the exhaustive description. Because the core structure involved reincorporating segments of the transcripts to let the participants' voices be heard, I decided to remove a few segments from the description that I felt were clearly addressed in the quotes from the interviews. Furthermore, one statement from the description associated with instructor 2 was slightly expanded because I felt that their earlier experience working with instructor 1 was a bit too brief. The corresponding author and I also added statements at the beginning of each narrative shift to better reflect its relationship with the emergent themes. We felt that this would help the readers see the relationship among the different parts of the analysis. The faculty also had an opportunity to view the core structure. Instructor 2 asked whether they could make minor edits to their interview quotes so that they would be easier to understand for the readers. We allowed the instructor to make these grammatical changes because we were sharing their experiences, and the meaning behind the experiences did not change with these edits. We gave the other faculty members the opportunity to edit their quotes as well, though declined as they felt that their quotes were fine as written.

Appendix D

Instructor 3's Return to the Participant Statements

How do the descriptive results compare with your experiences and perspectives?

There is much discussion about prior knowledge, and it is not clear to me that we are able to tell the difference between lack of prior knowledge and inability to understand when the prior knowledge should be applied. My class (and I think my colleagues' classes) began with an overview of gen chem and organic chemistry principles, including thermodynamics and pK_a. We do not need an entire semester to cover these topics, but rather do it in two to three weeks. I think that is clearly a sign that students have prior knowledge, but it needs refreshing prior to diving into new topics where there is context. I think most of the problem is that students have difficulty understanding the contexts to apply these concepts because in prior courses they learn pK_a and thermodynamics for the sake of learning them but do not apply them to complex systems. Meanwhile, there is huge context in biochemistry not only at the molecular level but at the far-reaching physiological level, a topic that many of our students find fascinating. For some students, biochemistry may be the first course that links chemistry with students' intrinsic motivations (e.g., pre-med, health students). It is also an early course that requires understanding the interplay of several chemical concepts, such as thermodynamic vs. kinetics. In many ways, biochemistry is one of the first opportunities where students apply their prior knowledge of chemistry concepts to more complex contexts and I am not sure what we are observing when we say the students "lack prior/background knowledge."

What aspects of your experiences and or perspectives have I omitted?

I am afraid I do not remember what I actually said. The interview was quite a long time ago.