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Cover Page Footnote

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Analysis of Attitudinal Student Learning Benefits from a Course-based Undergraduate Research Experience (CURE) Adapted for Online Format

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ABSTRACT

Course-based Undergraduate Research Experiences (CUREs) are an increasingly utilized model for exposing students to research. The lack of robust assessments is a major hurdle to wider adoption of CUREs. The Coronavirus Infectious Disease 2019 (COVID-19) pandemic necessitated a drastic shift of in-person courses to the online format. Using the Participant Perception Indicator (PPI) survey, we measured students' self-reported changes in learning from such a biochemistry course at a large university in south Florida based on the Biochemistry Authentic Scientific Inquiry Lab (BASIL) model. By doing this, we were able to better understand the student-benefits of CUREs and how these benefits are affected by changes in learning modalities between two relevant semesters, i.e., winter and summer of 2020. Anticipated learning outcomes (ALOs) help partially fill the gap left by the loss of physical interaction in experimental procedures. Our analysis indicated that students learned more through bioinformatic experiments compared to their wet-lab counterparts. Using pre- and post- surveys, students reported that their experience and confidence gains lagged behind their knowledge gain of technique-based skills. Students are not as confident in their understanding of techniques when unable to perform those in the physical laboratory. Thus, despite extensive pursuit of the purpose and protocols of the experiments and techniques, neither their experience nor their confidence was on par with their knowledge. This study is one of the first examples demonstrating a quantitative student-learning assessment of a CURE in the science, technology, engineering, and mathematics (STEM) disciplines. The novel assessment strategies targeted to identify gaps in learning mastery could facilitate the adoption of CUREs, fostering opportunities for all undergraduate students to vital laboratory research experiences in STEM.

KEYWORDS

Course-based Undergraduate Research Experience (CURE), laboratory instruction, COVID-19-mediated learning shift, online education, STEM education

Introduction

In midst of the Coronavirus Infectious Disease 2019 (COVID-19)-mediated shift to emergency remote instruction, many diverse curricular changes have been implemented. The abrupt nature of this shift has led to mixed success of these interventions (Chandrasekaran, 2020; Potgieter et al., 2019; Procko et al., 2020; Sommers et al., 2020). It has become increasingly important to clarify what students should be learning from their undergraduate biochemistry coursework (Sikora et al., 2020). The online environment has posed specific challenges in courses that traditionally contain a hands-on component, especially laboratory courses in STEM. Students who are not able to attend laboratories due to governmental restrictions or health issues are not exposed to hands-on practice with science concepts. This limitation extends to other traditionally hands-on methods of instruction such as skills in design and implementation of research projects**.** Course-based Undergraduate Research Experiences (CUREs) have long been used to teach both lab skills and research skills (National Academies of Sciences & Medicine, 2017; Shortlidge et al., 2017). Generally, five key features describe a CURE: collaboration, discovery, broad relevance, iteration, and use of science practices (Dolan, 2016). The nature of a CURE has been further described by other authors who outlined activities and experimental competencies to describe the nature of a CURE (Auchincloss et al., 2014; Bell et al., 2017; Seymour et al., 2004).

The Process for Identifying Course-based Undergraduate Research Abilities (PICURA) is a rigorous, five-step method consisting of a content analysis, an open-ended survey, an interview, an alignment check, and a two-tiered Likert survey (Irby et al., 2018b; Pelaez et al., 2016). The Biochemistry Authentic Scientific Inquiry Lab (BASIL) curriculum was designed to support the development of scientific thinking and inquiry-based learning in the undergraduate biochemistry teaching laboratory setting ((Irby et al., 2018a, 2018b; Sikora et al., 2020), McDonald, 2019). PICURA was applied to BASIL by Irby et al (Irby et al., 2018a), and served as the basis to develop a list of Anticipated Learning Outcomes (ALOs) (Table 1). These ALOs focus on BASIL-specific research abilities and are aligned with proposed experimental competencies (Irby et al., 2018a). Through BASIL, students learn how to propose hypotheses, design experiments, collect and analyze data, ask questions, draw conclusions, and propose future research directions. BASIL challenges students to predict the function of proteins with known structure but unknown function. Students accomplish this goal on their protein of interest (POI) by using a combination of computational and experimental tools. Protein homology-based alignments are employed to develop a hypothesis for the preferred substrate of their POI that has been structurally determined but not functionally characterized. Students test their hypotheses by expressing, purifying, and finally running an enzyme assay for their respective POI's function.

The ALOs represent diverse statements of learning that span the 11 experimental laboratory modules of BASIL. Some statements focus on individual experiments while others span multiple experiments focusing on complex themes that can only be developed through the combination of several experiments. We then used a Participant Perception Indicator (PPI) survey to delve more deeply into students' perceptions of their Knowledge, Experience, and Confidence (KEC) at both the beginning and end of the semester. PPI surveys have been adapted for measuring students' perceptions in chemistry and biology contexts (Glazer, 2015). The PPI survey was tailored to the BASIL CURE by Irby et al, and contains questions targeting specific ALOs, wet-lab techniques, and computational programs (Irby et al., 2019). The BASIL PPI survey proved to be an effective instrument for revealing changes in students' perceived KEC with respect to ALOs focused on research abilities. It also served to illuminate the effect of variations in BASIL implementation that affect student perceptions of their KEC. Furthermore, PPI findings are intended to provide useful feedback on how to improve instruction for faculty who want to identify and effectively correct areas of difficulty faced by students.

As the COVID-19 pandemic necessitated running in-person classes online from halfway through Winter 2020 and during the entire Summer 2020 semester, students were not able to take full advantage of this process, especially the wet-lab components. Rather, they spent more time reviewing computational methods of analysis, studying available and published data on their given POI, and developing a strong foundation of methodologies for how they would continue their studies in the lab once it was safe to do so. Since classes were taught completely online during the onset of the COVID-19 pandemic, it proved crucial to understand what students are learning, and not learning, especially in the laboratory setting. By understanding students' perceived learning gains in the BASIL CURE, we hope to identify gaps in student understanding of biochemistry and research methods. Ultimately, the objective of this work is to fill those gaps and thereby strengthen the effectiveness of research-based learning.

Student Demographics

Data for this study were collected from an upper-division biochemistry course at a large, private university in southeastern Florida, a U.S. institution classified as a Hispanic-serving, doctoral university with high research activity. This was a full-semester course in biochemistry with accompanying laboratory, taught during the Winter 2020 and Summer 2020 semesters. As a result of COVID-19, this in-person course was conducted completely online for both lecture and laboratory meetings in Summer 2020, following Winter 2020 when the course had to be shifted to the online format midway through the term due to the pandemic. There were 26 junior and senior students from two lab sections that participated in this study in Summer 2020, and nine students in Winter 2020. The participants spanned a variety of majors including Biology, Biochemistry, Chemistry, Behavioral Neuroscience, Public Health, and Sociology, with several students working on degrees in multiple fields. All students had previously completed organic chemistry and at least one semester of calculus successfully.

Anticipated Learning Outcomes (ALOs) Represent Diverse Topics and Methodologies

As an attempt to better understand student learning during BASIL courses, analysis on previously developed ALO statements, as described in Irby et al, was conducted (Irby et al., 2018a). These ALOs represent diverse statements of learning that span the 11 experimental lab-modules of BASIL. These learning objectives vary in focus. Some are specific to individual experiments while others cover multiple experiments which must be built upon each other to understand the overall process of experimentation.

Data in this study compared student gains in KEC for ALOs and laboratory techniques were measured using the PPI survey, which is developed for and tailored specifically to BASIL (Irby et al., 2019). It contains a set of questions targeting specific ALOs, wet-lab techniques, and computational programs. Participants self-reported their KEC perceptions via a Likert-scale ranging from 1 (none) through 5 (a great deal). Analysis of the PPI survey data was used to better understand students' perceived understanding/knowledge of the material, depth of experience with the concept, and confidence to repeat their work. ALOs are not aimed at basic biochemistry knowledge or skills, which are assessed in other course assignments. Rather, ALOs are focused on the higher levels of mastery. For example, this is reflected in the third ALO statement on the survey (ALO 3): "Determine the appropriate factors to consider when optimizing or interpreting an enzyme assay" (Table 1) (Roberts et al., 2019). The second part of the PPI survey substitutes statements with different computational programs and wet-lab procedures and then asks students to score their KEC, which ultimately yields information regarding their grasp of the techniques. The survey was given at the beginning and at the end of the academic term.

Measuring KEC for procedures is vital during the COVID-19 pandemic because online lab environments are not typically used when actively learning new scientific techniques and mastering new concepts. In an attempt to remedy this, videos showing laboratory procedures were shared with students when learning about wet-lab procedures. For computational experiments, the instructor was able to guide the students through the Zoom virtual meeting platform. In addition to technique videos, laboratory data from previous semesters and other lab sections in the same semester were shared with students. Students watched the lab procedure live, subsequently analyzing results representative of those they would have collected under traditional in-person wet-labs. Examples include SDS-PAGE gels, BSA protein concentration curves, and protein kinetics plots. The fundamental changes in instruction seen in 2020 especially impacted STEM lab courses. Student mastery in biochemical practical skills is expected to be negatively impacted by the lack of in-person experiences and engagement with wet-lab techniques.

BASIL Lab Protocols

Students filled out the PPI Survey during the first week of the semester so that a baseline of the students' KEC pertaining to the specific ALOs, wet-lab techniques, and computational techniques could be determined. In order to prepare the students for each lab, they were provided with a protocol and a pre-lab assignment via the Canvas learning management system (LMS). Lab sessions were conducted using the Zoom virtual meeting platform. In the case of computational labs, students used online programs to help them gain background information on their POI. During wet-lab protocols, videos from The Journal of Visual Experiments (JoVE) were provided to give students a visual experience of the experiments. Lab groups were subsequently provided with sample data acquired from previously conducted wet-labs. This allowed every group the opportunity to further analyze the function of their POI.

PPI Survey

In the PPI survey (Appendix 1), items have different formats depending on what is being assessed. The first 21 questions ask about the KEC on statements that consist of ALOs 1 through 7 (Table 1). These ALOs were identified as top-rated, based on weighted relevance, by the BASIL faculty (Roberts et al., 2019). Students were also asked to assess their KEC of computational programs and biochemical techniques. Items in this section consist of the technique or program name but maintain the KEC style for each set. One of the main strengths of BASIL is the curriculum's adaptive nature (Irby et al., 2018b). The PPI survey can be easily adapted for different techniques and programs that exist between one institution and another. The techniques selected for the survey analysis were the main focus of at least one experiment in this biochemistry course (Table 1).

As an internal negative control, PPI survey contains several question-sets regarding techniques that had not been discussed in the course. The PPI survey completed by students contained questions regarding cell culture, DNASU plasmid repository, and plasmid maps. There were no pre-lab or post-lab activities assigned corresponding to these topics to help ensure that students could display greater understanding of these topics. Several techniques showed high pre-survey values that changed little over the course of the semester. These techniques, including PubChem and cell culture, are part of the lab courses that many students in the same university take prior to biochemistry. The original PPI survey contains topics that were not explicitly taught during the biochemistry course but topics that students might have learned during previous courses. As shown in Figure 2, a set of 18 questions was removed in order to show how the results are influenced if data from this part of the PPI survey is used. If these excluded data points were to be considered, the calculations and the significant differences that we are seeing (i.e., students are making significant learning gains in both computational techniques and biochemical techniques) would be skewed.

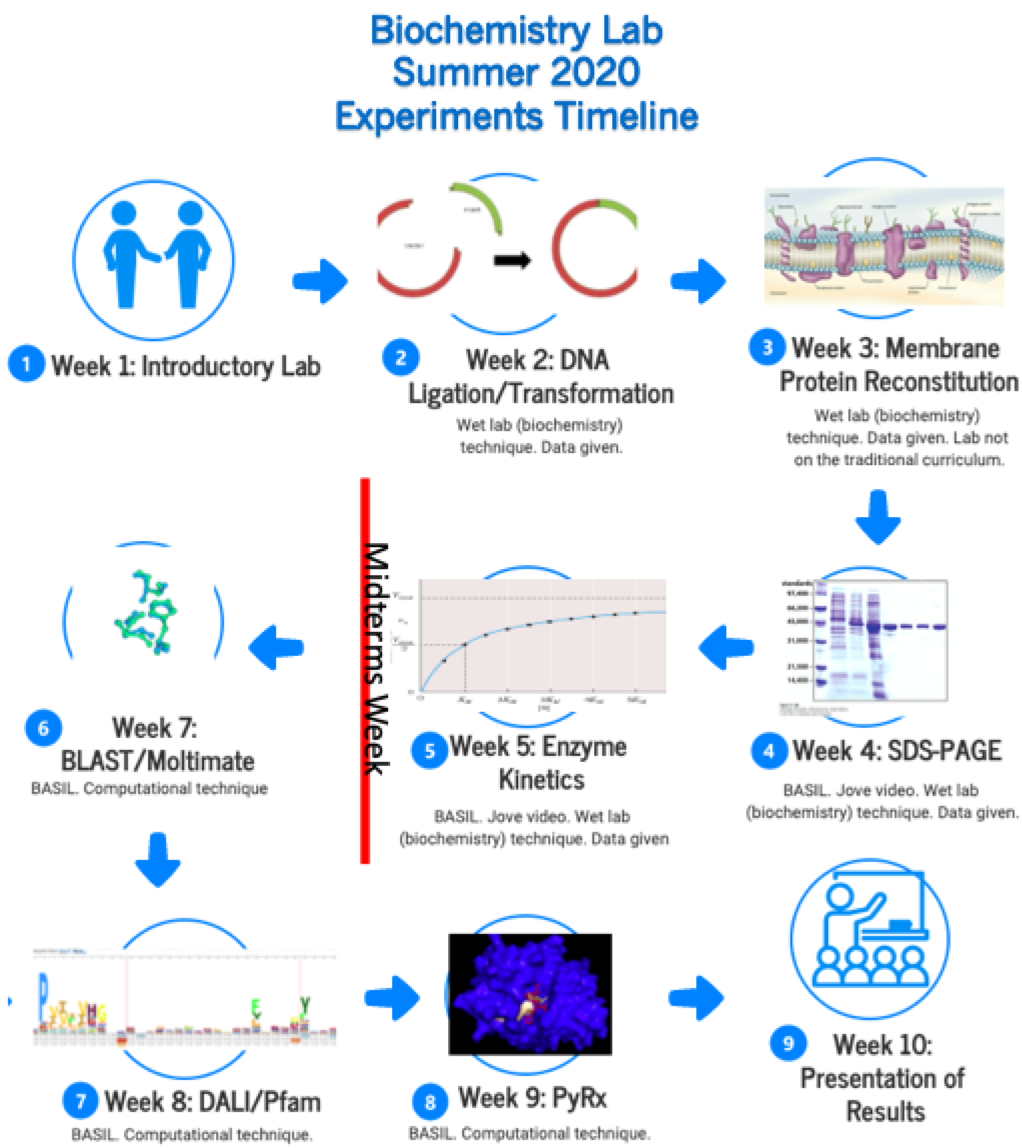


Figure 1: Schematic sequence of experiments conducted, and techniques employed during the Summer 2020 term. All experimental and computational procedures were conducted in an online learning environment. Students were provided with educational videos to help understand wet-lab experiments; the instructor was present to lead through computational techniques and explain questions or concerns.

Table 1: Descriptions of the Anticipated Learning Outcomes (ALOs) or Course-Based Undergraduate Research Abilities (CURAs) Studied Using the PPI Survey (Roberts et al., 2019).

ALO statements	*Description*	*BASIL CURE component*	*BASIL CURE Protocol(s)*
ALO 1	***Explain how the colorimetric enzyme assay works to allow detection of protein function***	***Biochem (B)***	***Enzyme Activity***
ALO 2	***Identify an enzyme active site using appropriate computational programs***	***Comp (C)***	***BLAST, PFam, Moltimate, PyRx***
ALO 3	***Determine the appropriate factors to consider when optimizing or interpreting an enzyme assay***	***Biochem (B)***	***Enzyme Activity***
ALO 4	***Determine using computational software whether, and where, a ligand may be binding to a protein***	***Comp (C)***	***PyRx***
ALO 5	***Compare enzymatic results with those computationally predicted***	***Both (B/C)***	***Covers multiple experiments***
ALO 6	***Design an enzyme assay to elucidate protein function***	***Biochem (B)***	***Enzyme Activity***
ALO 7	***Explain how the purification of tagged proteins work and ways the process can be optimized***	***Biochem (B)***	***Protein Purification***

Data Analysis

As described in Irby et al, 2020 (Irby et al., 2019), and subsequently employed in Sikora et al, 2020 (Sikora et al., 2020), the responses for KEC for each PPI item were averaged together to generate a score for each item, the average gain score. Originally, the data were arranged pertaining to either Biochemistry lab techniques (ALOs 1, 3, 6, and 7), Computational lab techniques (ALOs 2 and 4), or both (ALO 5), and the KEC averages were calculated (Table 1). Afterwards, 18 questions from the original PPI survey were removed to better reflect the actual techniques covered during the online lab during the Summer 2020 semester, leaving 60 questions in the PPI survey. These average KEC values (acquired after questions were removed) were then compared to see if there was any statistically significant difference. This significance between pre- and post-PPI responses were determined by performing an ANOVA test, with a p-value of < 0.01 considered as significant (Nahm, 2017). Lastly, population sizes differed, as a result of several students dropping the course and not completing the post survey. In order to have a directly comparable data set, a normalized gain of averages (gain scores) was calculated. The effect size was determined using Cohen's D with a value greater than 0.80 considered as a large effect. This comparison allowed for more insight into the extent of perceived gains in KEC, because large effect sizes are not always associated with significant gains. These statistics were implemented to represent how students perceived their gains in KEC within the BASIL CURE and how different activities affected their perceived gains. The findings were not used to directly evaluate the BASIL CURE or to make claims about how the BASIL CURE should be taught but could serve as the basis of such decisions in the future.

Results and Discussion

The first major finding of our study is that students reported strong learning gains across all learning outcomes and techniques despite the online environment of instruction. The PPI data revealed an overall increase of 46% in both biochemical and computational techniques. Similarly, for computational techniques there was an increase of 78% in the Summer 2020 semester compared to 73% in the Winter 2020 semester. These gains in ALO mastery demonstrate that, regardless of the instructional environment, students seem to consistently increase both their knowledge, learning, and comfort levels with computational techniques and computational ALO statements. Table 2 shows that students reported a significant increase in KEC with computational ALOs and bioinformatic techniques (81%) compared to those focused on wet-labs (54%).

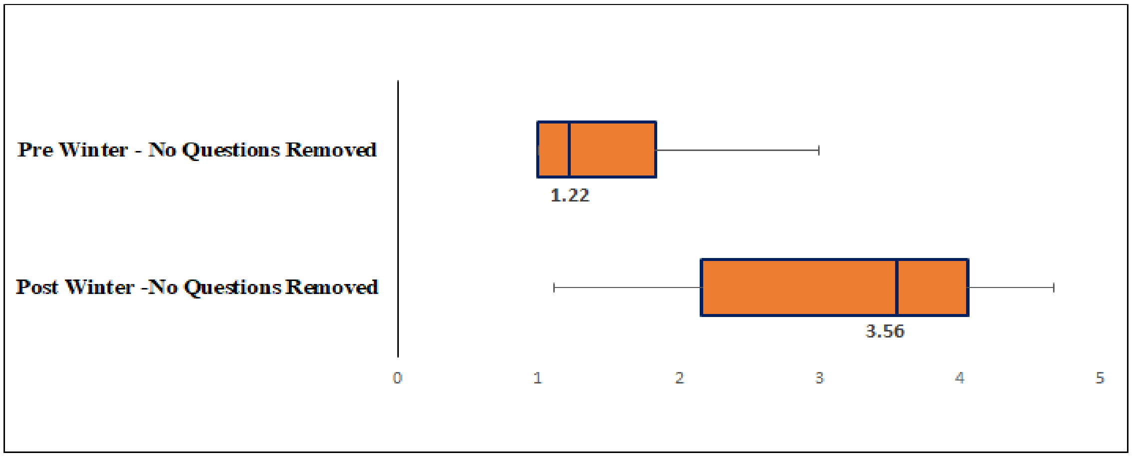
These non-uniform gains are not surprising, given the completely online teaching methodology of the course. Additionally, the gains demonstrate that the BASIL curriculum is an effective tool to increase understanding of complex biochemical techniques and the foundational concepts that foster robust research- and inquiry-based learning initiatives.

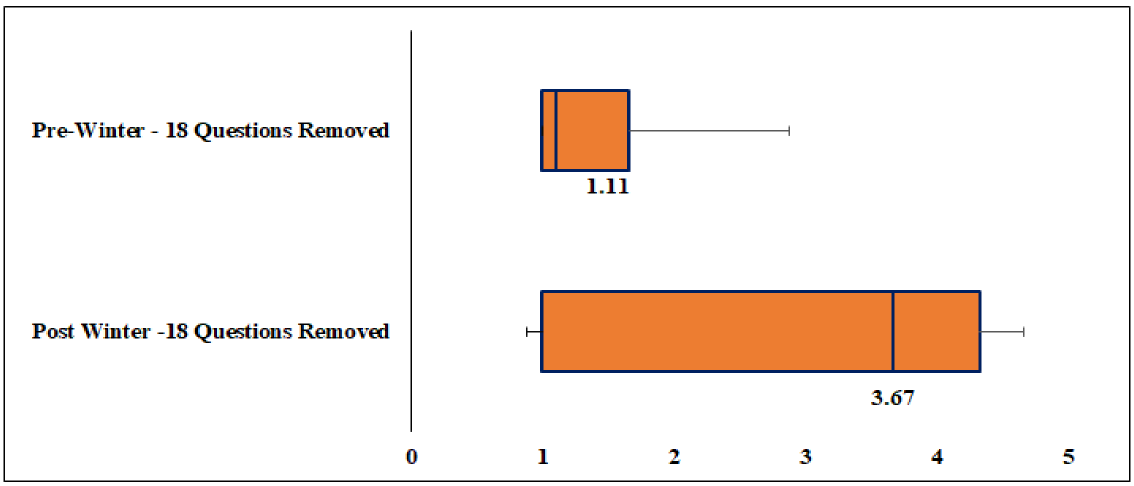
There was a lower increase in students' self-reported KEC for wet-lab/biochemical course topics compared to those utilizing bioinformatic tools. The development of ALOs specific to the BASIL curriculum resulted in very useful teaching tools, not only defining, and testing the extent of student learning, but also allowing for a directed effort to teach and assess those concepts. The ALOs allow for more directed research and experimental design skills. These statements represent a great deal of variety and diversity because they incorporate both procedural skills and an understanding of the bigger picture/experimental method. For instance, ALO 2 states, *"Identify an enzyme active site using appropriate computational programs".* This statement not only targets the students' understanding of the computational programs, but also connects this understanding with the overall purpose of the entire research project to find the active site of their protein and elucidate its function (Table 1). The gains in ALO statement mastery show a greater degree of growth compared to the biochemical lab techniques. This trend was also seen with the computational ALOs as well, although to a smaller degree. The wet-lab ALOs were numbers 1, 3, 6, and 7; they show an average gain score of 54%. Furthermore, the wet-lab techniques showed an average gain score of 46%. The computational lab ALOs were numbers 2 and

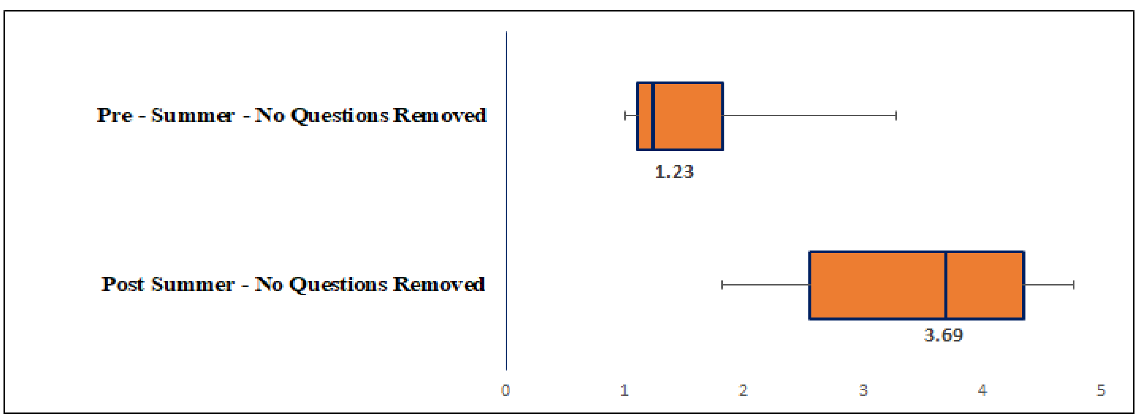
4, which showed an average gain score of 81%, while the computational lab techniques taught without ALOs showed an average gain score of 78%. ALO 5 contains both computational and biochemical aspects and showed a gain score of 64.5%. Use of these ALOs may be a viable means of working to overcome the decrease in students' self-reported KEC perceptions.

Table 2: Reported Knowledge, Experience, and Confidence gains broken down into computational and biochemical, ALO and technique-based categories.

Classification	Average Gain Score (%)	Knowledge Gain Score (%)	Experience Gain Score (%)	Confidence Gain Score (%)
Biochemical ALOs	53.98	58.88	50.79	52.79
Computational ALOs	81.24	84.27	81.63	78.01
Biochemical Techniques	46.07	34.38	45.38	47.71
Computational Techniques	77.92	81.24	77.71	74.94


Pre Winter - No Questions Removed
Post Winter -No Questions Removed
1.22
3.56
0
1
2
3
4
5


Pre-Winter - 18 Questions Removed
Post Winter -18 Questions Removed
1.11
3.67
0
1
2
3
4
5


Pre - Summer - No Questions Removed
Post Summer - No Questions Removed
1.23
3.69
0
1
2
3
4
5

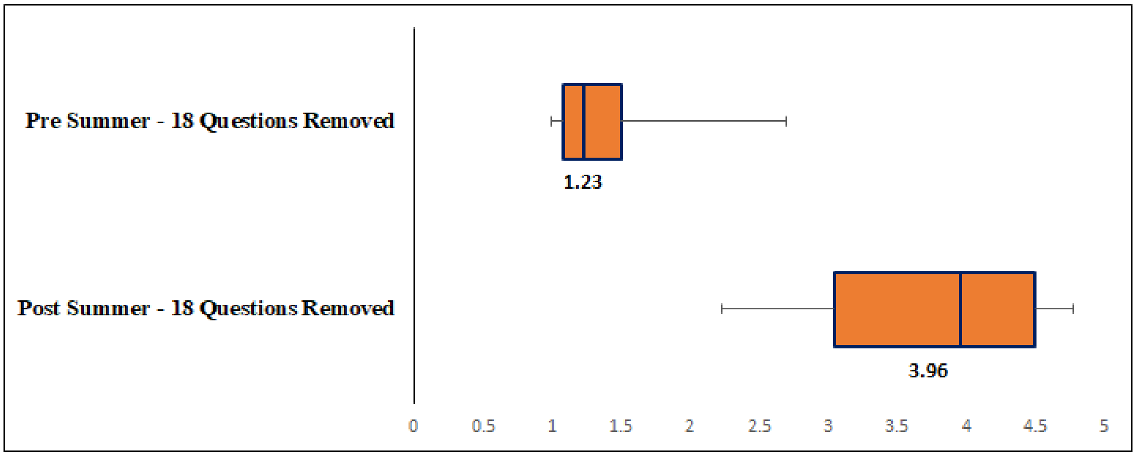


Figure 2: Plots of the pre-PPI with no questions removed (2A and 2C) and post-PPI with no questions removed (bottom of 2A and 2C) pre-PPI with 18 questions removed (top 2B and 2D) and post-PPI with 18 questions removed (bottom of 2B and 2D). ALO ratings for both winter 2020 (n = 9) and summer 2020 (n=26) are provided on a scale from 1-5. In all of the plots, the square dots indicate the average, and the whiskers represent the 95% confidence interval.

Table 3: PPI results for Summer 2020 compared to Winter 2020 results

Metric	ALO 1 (B)[b]	ALO 2 *(C)*[b]	ALO 3 *(B)*[b]	ALO 4 *(C)*[b]	ALO 5 (B/C)[b]	ALO 6 (B)[b]	ALO 7 (B)[b]	Average ALO	Comp. Tech.	Biochem Tech.
Summer 2020 Data; n = 26										
Pre-PPI Score [a]	1.36	1.42	1.46	1.33	1.64	1.35	1.82	1.48	1.19	1.66
Post-PPI Score [a]	2.88	4.32	3.71	4.32	3.81	3.32	3.64	3.71	4.16	3.2
Change in score	1.53	2.9	2.24	2.99	2.17	1.97	1.82	2.23	2.97	1.54
Gain Score	42%	81%	63%	81%	65%	54%	57%	63%	78%	46%
Cohen's D	1.62	3.87	2.62	5.09	2.03	2.18	1.72	3.62	6.74	1.99
p-value	< 0.00001	< 0.0001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.0001	< 0.00001
Winter 2020 Data; n = 9										
Pre-PPI Score [a]	1.37	1.44	1.37	1.19	1.7	1.7	1.67	1.49	1.12	1.73
Post-PPI Score [a]	3.67	4.07	3.59	3.74	3.96	3.3	3.89	3.75	3.97	3.11
Change in score	2.3	2.63	2.22	2.56	2.26	1.59	2.22	2.25	2.85	1.38
Gain Score	63%	74%	61%	67%	69%	48%	67%	64%	73%	42%
Cohen's D	4.67	3.84	4.83	3.95	3.68	1.87	2.97	5.98	7.07	3.21
p-value	< 0.00001	< 0.0001	< 0.00001	< 0.0001	0.0001	0.006	0.0012	< 0.00001	< 0.0001	0.0001

There are noticeable differences between the PPI survey results from Winter 2020 and Summer 2020 semesters (Table 3). However, it is important to keep in mind the context in which these semesters occurred. The Winter 2020 semester was split midway by COVID-19-mandated quarantine while Summer 2020 students completed the course entirely online.

The results show a much greater increase in computational technique gain scores compared with wet-lab technique gain scores. The computational techniques overwhelmingly fared better than biochemical techniques, from a 74% gain score in ALO 2 in Winter to an 81% gain score in Summer, and from a 67% gain score for ALO 4 in Winter to an 81% gain score in Summer. This was expected since computational techniques were more readily transferable to an online environment where the instruction can be guided via online meetings. Biochemical procedures are much more difficult to convey virtually since instructors are not able to let the students produce their own results firsthand, and instead, students must watch online supplemental instruction, like videos utilized from JoVE, to experience it. Thus, these methods are more difficult to teach in the online environment. Biochemistry students reported having an increased understanding of biochemical/wet-lab techniques. The data showed an increase in Winter 2020 KEC scores to Summer 2020 KEC scores, going from a 35% gain score average to a 54% gain score, respectively. These changes in gain scores help show how new methods of remote instruction such as videos, pre- and post-quizzes, and interactive laboratory sites are effective ways of teaching students the critical biochemical techniques.

Undoubtedly, the events of the past year have had, and will continue to have, a great impact on the way students are instructed and their grasp on the material. Moving to the online format benefited the understanding of computational concepts in the course, while mastery of the wet-lab skills was lagging.

Implications

In every case where the techniques taught are paired with their respective ALOs, there was a clear increase in knowledge, experience, and confidence. In many cases, the gains in experience and confidence are lower than the gain in knowledge. Published data from the Winter 2020 semester show that the knowledge gains were at par with gains in experience and confidence. In wet-lab techniques, experience yields the lowest gain score. In computational techniques, confidence shows smallest gains. Students seem to gain plenty of experience and knowledge in computational techniques when paired with ALOs, they are still lacking overall confidence. The data presented here leads to the conclusion that there must be improvement in how wet-lab techniques are taught to students in an online environment. It becomes quite apparent that a more comprehensive focus and approach towards these factors is needed in order to enhance teaching and learning outcomes in an online lab environment. Furthermore, pre-pandemic pooled PPI data, reported in Irby et al, 2020, shows significantly less variation in gain scores between biochemical and computational ALOs (Glazer, 2015). These data are reported as aggregate gain scores and not separated into the KEC components. All three studies analyzing data on BASIL PPI results show a greater gain in student-reported computational learning gains over those related to biochemical/wet-lab learning gains.

PPI survey data is, by nature, based on students’ perceptions of learning and may not accurately reflect the actual gains in learning. Future work analyzing larger populations of students across multiple semesters will help reveal gaps in student learning. This attitudinal gain dataset can then be analyzed to understand the impact of future interventions and improvements in BASIL, elucidating the impact on diverse populations of students and varying modalities of delivery. Analysis of actual learning gains will also be essential for understanding the complete picture of CURE learning gains. This can be done by analyzing BASIL student-artifacts designed to correlate with anticipated learning outcomes. Such studies, currently underway being a combination of self-reported and empirical learning gains, will provide a clearer picture of what impact CUREs like BASIL have on the students that participate in them. It is hoped that these data, and future experiments detailing the benefits of CURE courses, will spur instructors and administrators to wider adoption of research-based undergraduate curricula in STEM disciplines.

SUPPLEMENTAL CONTENT

PPI survey (Appendix 1)

COMPETING INTEREST

The authors declare no competing interest.

AUTHORS' CONTRIBUTIONS

AK: data curation, formal analysis, methodology, visualization, writing original draft, review and editing; LG: data curation, formal analysis, writing original draft; NP: formal analysis, validation, review and editing; SD: conceptualization, data curation, formal analysis, supervision, validation, writing original draft, review and editing; AS: conceptualization, data curation, formal analysis, project administration, supervision, writing original draft, review and editing.

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Appendix 1

PPI Student Survey

The purpose of the following survey is to measure your perception of your learning about various topics that were covered in this biochemistry laboratory course. The items are organized into three categories: research abilities, computational techniques and biochemical techniques. Please answer the items honestly and thoughtfully by rating each ability or technique on the supplied Likert scale to show how you currently feel about your: 1) **Knowledge**, 2) **Experience**, and 3) **Confidence**, with respect to each topic that you may have encountered in this course.

EXAMPLE: Changing a flat tire.

Knowledge		**Experience**		**Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	**B.**	**A little**
C.	Some	**C.**	**Some**	C.	Some
D.	Much	D.	Much	D.	Much
E.	**A great deal**	E.	A great deal	E.	A great deal

If you had been taught how to repair a car in this course, you might think that you have "A great deal" of **Knowledge** about changing a flat tire, "Some" **Experience** with changing a flat tire, but only "A little" **Confidence** in your ability to change a flat tire.

<u>Category 1:</u> Research abilities you may have gained or experienced as part of the course

Question 1-21
Indicate your feelings of knowledge, experience, and confidence about the following:

Explain how the colorimetric enzyme assay works to allow detection of protein function.

Q1 Knowledge		**Q2 Experience**		**Q3 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Identify an enzyme active site using appropriate computational programs.

Q4 Knowledge		**Q5 Experience**		**Q6 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Determine the appropriate factors to consider when optimizing or interpreting an enzyme assay.

Q7 Knowledge		**Q8 Experience**		**Q9 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Determine using computational software whether, and where, a ligand may be binding to a protein.

Q10 Knowledge		**Q11 Experience**		**Q12 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Compare enzymatic results with those computationally predicted.

Q13 Knowledge		**Q14 Experience**		**Q15 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Design an enzyme assay to elucidate protein function.

Q16 Knowledge		**Q17 Experience**		**Q18 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Explain how the purification of tagged proteins work and ways the process can be optimized.

Q19 Knowledge		**Q20 Experience**		**Q21 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

<u>Category 2:</u> Computational programs and databases you may have used as part of the course.

Questions 22-57
Indicate your feelings of knowledge, experience, and confidence about the following:

Autodock

Q22 Knowledge		**Q23 Experience**		**Q24 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

BLAST

Q25 Knowledge		**Q26 Experience**		**Q27 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Dali

Q28 Knowledge		**Q29 Experience**		**Q30 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

DNASU

Q31 Knowledge		**Q32 Experience**		**Q33 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

LigPlot+

Q34 Knowledge		**Q35 Experience**		**Q36 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

PDB

Q37 Knowledge		**Q38 Experience**		**Q39 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Pfam

Q40 Knowledge		**Q41 Experience**		**Q42 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Plasmid maps

Q43 Knowledge		**Q44 Experience**		**Q45 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

ProMOL

Q46 Knowledge		**Q47 Experience**		**Q48 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

PubChem

Q49 Knowledge		**Q50 Experience**		**Q51 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

PyMOL

Q52 Knowledge		**Q53 Experience**		**Q54 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

PyRx

Q55 Knowledge		**Q56 Experience**		**Q57 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

<u>Category 3:</u> Biochemical assays, methods, or tools you may have used as part of the course.

Questions 58 - 78
Indicate your feelings of knowledge, experience, and confidence about the following:

Protein expression

Q58 Knowledge		**Q59 Experience**		**Q60 Confidence**	
A.	None	A.	None	**A.**	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Cell culture and growth

Q61 Knowledge		**Q62 Experience**		**Q63 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Metal ion affinity chromatography

Q64 Knowledge		**Q65 Experience**		**Q66 Confidence**	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some

D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Bradford assay

Q67 Knowledge		Q68 Experience		Q69 Confidence	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

SDS-PAGE

Q70 Knowledge		Q71 Experience		Q72 Confidence	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Activity assay with p-nitrophenyl acetate

Q73 Knowledge		Q74 Experience		Q75 Confidence	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal

Western blot

Q76 Knowledge		Q77 Experience		Q78 Confidence	
A.	None	A.	None	A.	None
B.	A little	B.	A little	B.	A little
C.	Some	C.	Some	C.	Some
D.	Much	D.	Much	D.	Much
E.	A great deal	E.	A great deal	E.	A great deal