Teaching Acid-Base Homeostasis Using Collaborative, Problem-based Learning and Human Patient Simulators in a Physiology Laboratory.

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Teaching Acid-Base Homeostasis Using Collaborative, Problem-based Learning and Human Patient Simulators in a Physiology Laboratory

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Abstract
Students find it hard to understand acid-base homeostasis and the mechanisms involved in compensating for acid-base imbalances, including the role of the lungs and kidneys in this process. We have developed a laboratory activity based on collaborative problem-based learning and human patient simulators (HPSs) to teach this topic. Students (n=50) were divided into small groups and presented with five cases of acid-base imbalances simulated in HPSs. After recording various parameters including arterial blood gases, they collaborated in identifying the specific acid-base imbalance. An anonymous survey following the laboratory activity revealed that this laboratory improved their understanding of acid-base regulation (92%), improved quantitative understanding of acid-base physiology (90%), and improved understanding of acid-base imbalances (94%). https://doi.org/10.21692/haps.2018.013

Key words: acid-base homeostasis, pH imbalances, collaborative active learning, human patient simulators

Introduction
Educators employ various instructional methods to enhance student comprehension of difficult concepts and to help students develop independent problem-solving skills in particular areas. Since no one method is effective for teaching everything (Myers and Dyer 2006) there is a constant search for the best teaching methods to help instructors achieve their goals. Active learning is a method that has been found to be useful for teaching difficult concepts. Research suggests that active learning helps students develop the ability to think logically and to reflect upon known information (Paul and Elder 2001). Specifically, problem-based active learning engages students in finding solutions to real life situations, instills curiosity, and helps to transform students into lifelong learners. In this lab, the active learning component consisted of five human patient simulators (HSPs) that were used to simulate five acid-base disorders.

Collaborative learning is a teaching method that helps make learning enjoyable. It is a natural social act in which the students talk among themselves (Gerlach 1994). In collaborative learning, students have the opportunity to converse with peers, present and defend their ideas, exchange diverse beliefs, question other conceptual frameworks, and be actively engaged in the learning process (Smith and MacGregor 1992).

We used a combination of problem-based active learning and collaborative learning to teach acid-base homeostasis and simple acid-base imbalances. We believe that when both of these methods are combined they make it easier for students to understand the material, reflect upon what they have learned and retain their knowledge. We incorporated these methods of instruction into a laboratory activity in a physiology laboratory course (BIOL369). This laboratory is offered concurrently with the physiology lecture (BIOL368) course at Gannon University, Erie, PA. USA.

Materials and Methods
Five HPSs (Patient # 1- 5) were used to simulate five pH imbalances:

1. Partially compensated metabolic acidosis with high anion-gap.
2. Uncompensated acute respiratory acidosis.
3. Partially compensated metabolic alkalosis.
4. Compensated metabolic acidosis with normal anion-gap.
5. Uncompensated acute respiratory alkalosis.

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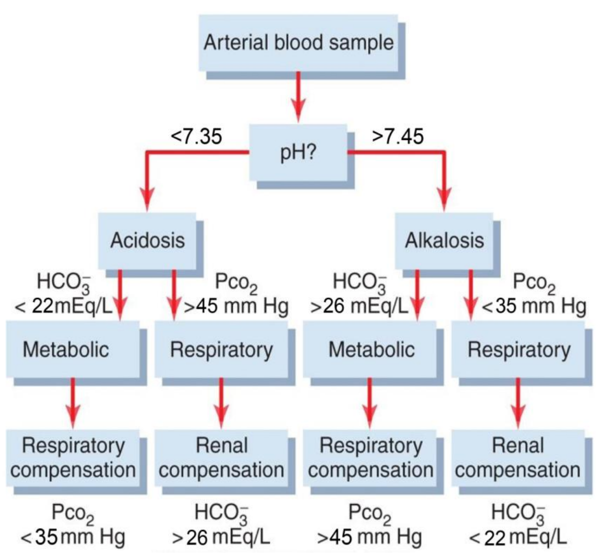
After a brief lecture on acid-base homeostasis and associated disorders at the beginning of the lab, students formed into small groups (three students/group) to work at the HPS stations. They recorded arterial blood gas (ABG) values, electrolyte levels (Na^+, K^+, Cl^-, $HCO3^-$), and other parameters from each of the stations in their laboratory report (Table 1).

Staying in the same group, students discussed and reasoned with each other to identify the imbalance and they completed the rest of the Table 1 calculations. Students used Figure 1 to identify the type of acid-base imbalance simulated and the level of compensation designated as complete, partial or no compensation. Figure 1 was adapted from the Guyton and Hall Medical Physiology textbook and is slightly modified for ease in making the required calculations.

Table 1. Identify the acid-base imbalances and the type of compensation simulated in patient simulators #1-5

Physiological Parameters	**Patient # 1**	**Patient # 2**	**Patient # 3**	**Patient # 4**	**Patient # 5**
pH	7.27	7.08	7.5	7.35	7.52
PCO_2	23	80	49	26	26
HCO3-	10	22	37	14	22
Na+	133	140	142	135	140
K+	6	4	5	3.3	5
Cl-	93	100	101	111	105
$\%0_2$ Saturation	91	89	93	95	92
Breathing Rate	12	5	12	14	17
Heart Rate	78	85	82	75	102
Blood Pressure	110/78	140/85	100/70	150/95	130/84
Expected pH					
Expected HCO3- in respiratory imbalances					
Expected CO2 in metabolic abnormalities					
(for metabolic acidosis only) Is this normal or high anion-gap and how much is the gap?					
(for respiratory imbalances only) Is it acute or chronic?					
Identify the degree of compensation and the systems compensating	Partial Compensation Respiratory	Not compensated	Partial compensation Respiratory	Complete Compensation Respiratory	Not compensated
Diagnosis	**Metabolic acidosis**	**Respiratory acidosis/acute**	**Metabolic alkalosis**	**Metabolic acidosis**	**Respiratory alkalosis**

*Figure 1. Flowchart for the analysis of simple acid-base imbalance**



**The flowchart in Figure 1 is adopted from Guyton and Hall's textbook of Medical Physiology (11th edition, 2006) and slightly modified for ease in the analysis of simple acid-base disorders.*

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After all of the students had finished their work, instructors disclosed the answers and verified their calculations. After the lab was completed, students' anonymous responses on the usefulness of a problem-based learning method in the understanding of acid-base homeostasis and imbalances were collected. Informed consent was obtained form those who participated in this study. Since the survey was anonymous and did not contain any personal information, the Institutional Review Board of Gannon University did not require an IRB application for this study.

Results

Student responses to the five questions in the questionnaire are shown in five pie diagrams (Figures 2-6). Analysis of student feedback revealed that the majority of students liked working with their peers and expressed high satisfaction in this learning activity.

Figure 2. Does this lab improve your understanding of acid-base regulation?

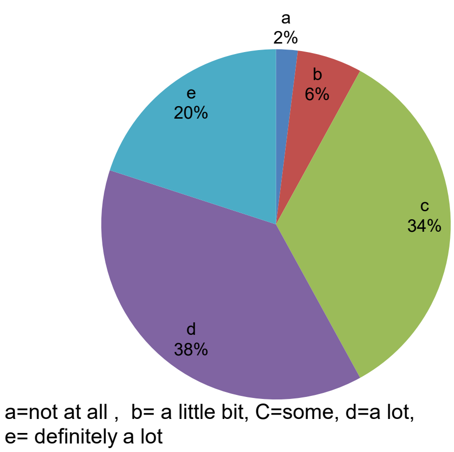

Figure 3. Does this lab improve your understanding of the role of pulmonary and renal systems in acid base regulation?

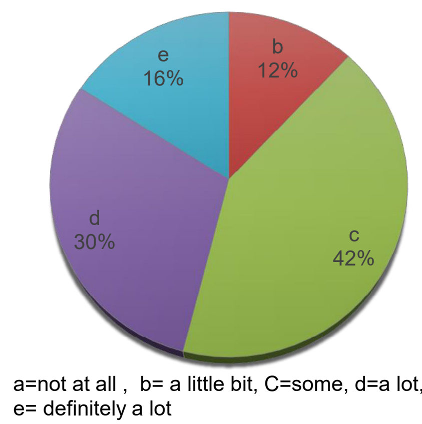

Figure 4. Does the calculating activities in this lab improve your quantitative understanding of acid base physiology?

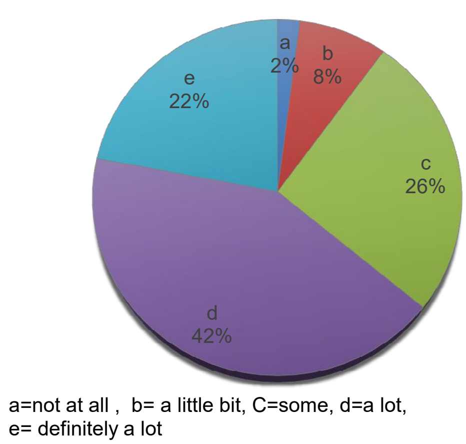

Figure 5. Students' feedback on their preference of acid-base lab with simulators to urine-based renal lab.

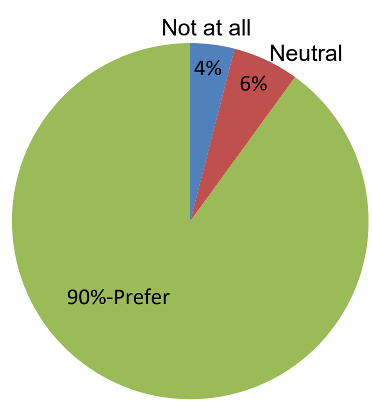

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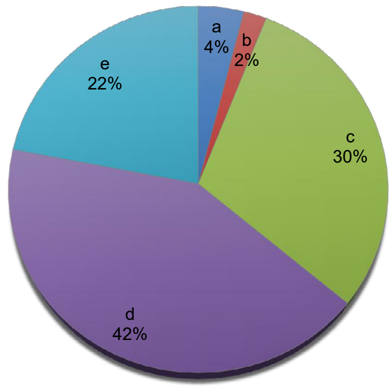
Figure 6. Does this lab improve your understanding of various acid base imbalances?



a=not at all , b= a little bit, C=some, d=a lot, e= definitely a lot

Conclusion

Fluctuations in the concentrations of H^+, HCO_3^- ions, partial pressure of carbon dioxide (P_{CO2}) and the subsequent changes in pH, along with compensation by the renal and respiratory systems to minimize these changes, can be difficult concepts for students to understand. In this laboratory, we attempted to teach acid-base homeostasis through the use of simulated pH imbalances. We simulated five pH imbalances in HPSs. Students were able to retrieve their previous knowledge of normal ABG values and compare them with simulated values in order to solve a problem or identify a type of pH imbalance.

After identifying the type of pH imbalance, students were asked whether there had been enough compensation by the renal or respiratory systems. In the case of metabolic acidosis they were required to distinguish between a high anion gap or a normal gap acidosis in order to make a further diagnosis. The anion gap is the difference between the measured cations and the measured anions in blood (or urine) and the extent of this gap is used to identify the cause of metabolic acidosis.

All of the activities in this laboratory require critical thinking and logic and we believe this laboratory activity was successful in honing these skills. Students responses (Figures 2-6) for this lab activity serve as evidence of this. Ninety-two percent of students agreed that this lab improved their understanding of acid-base imbalance and 88% stated that this lab helped in understanding of the role of the lungs and kidneys in pH regulation. Additionally, 90% students indicated that their quantitative skills also improved following this activity and 94% indicated that they gained understanding of pH imbalances and associated disease processes. Overall, it is clearly evident that collaborative problem-based learning is well received by students and is effective in teaching acid-base imbalances.

Many reports (Barkley *et al*. 2014, Davidson *et al*. 2014) show positive educational outcomes with this type of teaching strategy. Before adopting this new laboratory activity, we taught a lab on a similar topic using the students' own urine (pH changes in urine after imbibing different solutions). Though these students did not do the previous urine-based laboratory, the majority (90%) stated that they would prefer the active learning laboratory activity to the urine-based lab. We believe that the objectives of increasing student engagement, improving critical thinking skills and improving collaberative skills are met by this laboratory activity.

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