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ORIGINAL PAPER

Oximetry: a reflective tool for the detection of physiological expression of emotions in a science education classroom

Olga Calderón[1]

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Abstract The pulse oximeter is a device that measures the oxygen concentration (or oxygen saturation—SpO_2); heart rate, and heartbeat of a person at any given time. This instrument is commonly used in medical and aerospace fields to monitor physiological outputs of a patient according to health conditions or physiological yields of a flying pilot according to changes in altitude and oxygen availability in the atmosphere. Nonetheless, the uses for pulse oximetry may expand to other fields where there is human interaction and where physiological outputs reflect fluctuations mediated by arising emotions. A classroom, for instance is filled with a plethora of emotions, but very often participants in this space are unaware of others' or their own sentiments as these arise as a result of interactions and responses to class discussions. In this paper I describe part of a larger study-taking place at Brooklyn College of the City University of New York. The focus is on the exploration of emotions and mindfulness in the science classroom. The oximeter is used in this study as a reflexive tool to detect emotions emerging among participants of a graduate History and Philosophy of Science Education course offered in the spring of 2012. Important physiological information of class participants provided by the oximeter is used to analyze the role of emotions in the classroom as sensitive and controversial topics in science education are discussed every week.

Keywords Pulse oximetry · Oxygen saturation · Emotions · Mindfulness

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✉ Olga Calderón
ocalderon@lagcc.cuny.edu

[1] Natural Sciences, LaGuardia Community College, 3110 Thomson Avenue, Long Island City, NY 11101, USA

My role was of an observer when the Brooklyn College project began. I was there to learn data collecting methods and other intricacies of qualitative research. In addition, I was going to serve as a peer de-briefer for some of my colleague researchers. When I attended the first class, I realized that I was not only learning about research in the classroom, but I had become part of the research.

I became interested in aspects of the research that dealt specifically with emotions, their analysis, and their origin. Coming from a biological background, the subjectivity of the methods of analysis looked quite appealing and posed a new perspective for me. I noted from the beginning that this project reached beyond collecting and reporting data, because there was a sense of axiological transformation for all involved. One of the factors that attracted me to the project was the intersection of sociocultural themes that emerged every night as a result of discussions in the classroom. Class discussions coupled with diverse emotional and physiological experiences and responses from all participants (researched and researchers) as the course curriculum was being enacted, was quite revolutionary to me. The emergent and contingent style of our research depended upon the developments of class events. This approach enabled us to incorporate methodologies that were discussed on a day-to-day basis during cogenerative dialogues. Cogenerative dialogue has been described by Kenneth Tobin, as a practice whose membership represents all stakeholder groups that dialogue about specific incidents occurring in the classroom. Their purpose is the improvement of schools and learning environments (Tobin and Roth 2005). Cogenerative dialogues took place before and after each class and in a formal weekly meeting, at the CUNY Graduate School and University Center. Here, new ideas on the course of the research were contemplated. This research structure, gave strength to the methods, data collection, and emergent situations during the research process. In addition to data collection using video recorders to capture events for facial, voice, and proxemics analysis, we also used digital clickers to collect responses from participants on what they perceived as the emotional climate being experienced in the classroom. Coteachers and researchers used finger pulse oximeters during class presentations and discussions, which provided in the moment physiological data that were used to make participants aware of their physiological measures related to their emotions. The physiological data were in turn used to introduce the practice of breathing meditation as an intervention activity that could ameliorate the physiological stress participants were experiencing. Moreover, numerous heuristic instruments, including coteaching and mindfulness, were developed and tested by the participants. The inclusiveness of such diverse, yet complementary methods of analysis provided reinforcement to the research process and a strong platform where developed instruments intersect, providing new and valuable information to research in science education. Here, I document oximeter data collected for two student teachers enrolled in a history and philosophy of science education course at Brooklyn College in the spring 2012. These two participants presented unusual spikes in the curves for oxygen saturation (SpO_2) and heart rate (HR) on the days they were scheduled to coteach. I became interested in learning how the pulse oximeter worked and how it could be used in the classroom as an intervention tool to become aware of changes in physiology as emotions change, especially since the curriculum in this class is designed to discuss sensitive science-related issues. Also, I wanted to explore what strategies coteachers might employ to enable other class participants to express their agency freely and still maintain a sense of respect, tolerance and compassion among all class participants. The data we collected gave us important insights into the application of oximeters in the classroom and possible benefits for the overall wellness of teachers. Our research is perhaps one of a few of this kind, where the use of multi-methods is employed to explore emotions and mindfulness as a transformative approach to teaching and learning.

Why use this medical device in class?

The finger pulse oximeter is very easy to use; it is inexpensive and provides great feedback about emotional wellness. The oximeter slips onto your fingertip and measures arterial oxygen saturation (oxyhemoglobin) by shining red and infrared light through the tissue. It measures arterial pulsations and pulse rate at 18–300 beats per minute (bpm). Its accuracy is within 2 % (Furgang 2012). After World War II, many of the scientific advances reached in aviation medicine transferred over to respiratory physiology in hospitals and the general medical field. One of the first reported uses of the oximeter was during a surgical anesthesia procedure to control anoxemia. The development of oximetry has transformed the diagnostic accuracy of oxygen saturation in the blood. We often do not think of the classroom as a place that can have an effect in our health. Konstantinos Alexakos and Tobin developed the idea of utilizing oximetry to monitor emotions in the science classroom and use it as a resource to improve teachers' praxis. Tobin had used an oximeter on himself and some of his graduate classes to explore its applications in education. He realized that since its development, numerous applications in military aviation and the medical field have proven to save lives in flying missions as well as in the operating room and improving patient safety. After looking at the effective use that pulse oximetry has had in these fields, Tobin and Alexakos thought of expanding its practical application by incorporating the instrument as part of our multilevel research methods in the science education research at Brooklyn College.

The development of the oximeter

The development of oximetry is the result of an accumulation of science discoveries in the physical properties of blood, the physiology of blood vessels, the respiratory system, and the transmission and absorbance of infrared light by blood through skin. This accumulation of discoveries dates back to the nineteenth-century, when scientists researched and built on light transmission, optical density, and gas laws. These and other developments in the physical sciences coupled with advances in biological molecular structure and function are the baseline for the development of the pulse oximeter.

George Stokes discovered that the colored substance in blood was the carrier of oxygen. By the end of the 19th century, Felix Hoppe-Seyler had isolated and crystalized this pigmented substance and named it "hemoglobin." In his experiments, Hoppe-Seyler was able to prove and conclude that hemoglobin was the cause of absorption of blue and green light from the solar spectrum and that its absorption changed when he shook the solution with air. He also showed that oxygen and hemoglobin formed a dissociable compound, which he called "oxyhemoglobin." At the same time that these discoveries were happening, Kurt Kramer used the relationship of light transmission and optical density, also known as the "Lambert-Beer Law" to measure the saturation of oxygen in hemoglobin by the transmission of red light through unopened arteries (Severinghaus and Astrup 1986). This procedure was later enhanced by introducing a second wavelength of green or infrared light that is insensitive to saturation to compensate for blood volume and tissue pigments. The majority of these advances were being done in Germany. Yet, the value and possible application of such concepts had awakened the interests of researchers around the world; hence experiments and scientific collaborations sped up the process of development of an instrument to measure dangerous levels of oxygen limiting conditions. An industry that was extremely interested in the new advances was the military. Before World War II (WWII), military aircraft did not have pressurized cabins and lacked oxygen when flying above 10,000 feet of altitude. At high altitudes habitation is inhospitable for sustained human life. The primary factor is barometric pressure that decreases exponentially with increase altitude. At sea level barometric pressure is approximately 29.92 inches of mercury (in Hg). At high altitudes barometric pressure can decrease to 1/3 of the values at sea level. Because oxygen makes up 21 % of air at any altitude, the partial pressure and availability of oxygen decreases with altitude (Huey and Eguskitza 2001). Such conditions could create dangerous hypoxic conditions for pilots, called hypoxic hypoxia or altitude hypoxia. Hypoxic hypoxia is characterized by decreasing amounts of oxygen available on ascent in the atmosphere (Furgang 2012). As a plane ascends, the pressure decreases and there is less concentration of oxygen in the air. Thus less oxygen is available for pilots. The low partial pressure of oxygen at this altitude reduces the alveolar oxygen tension in the lungs; therefore there is less oxygen for the blood to carry to tissues, including the brain. This condition can lead to sluggish thinking, dimmed vision, unconsciousness and ultimately death. Depending on the health state of the person, especially individuals with heart and lung disease, symptoms may start at an altitude as low as 5000 feet (Furgang 2012). In 1945, researchers at the University of Pennsylvania were investigating the supposed alveolar-to-arterial oxygen tension gradient. They were able to show that human hemoglobin was 98.5 % saturated. This was important because it meant that there is almost no measurable oxygen gradient between the alveolar gas and arterial blood. At the same time it was discovered that carboxyhemoglobin (blood rich in carbon dioxide) was transparent to infrared light and in contrast hemoglobin had about half the absorption of oxyhemoglobin in the band from 900 to 1000 nanometers (nm). This was a critical piece of information because it indicated an increase in pulse oximeter signals well above the isosbestic point (The isosbestic point refers to a specific wavelength at which both hemoglobin and carboxyhemoglobin absorbance cross each other) (Severinghaus and Astrup 1986). Today's pulse oximeter measures light at only two wavelengths: 660 and 940 nm, which is more of a red or near infrared wavelength. The ratio of the absorbance at the two wavelengths is the basis for the oximeter calculating oxygen saturation. The pulsatile absorbance corresponds to arteriolar contributions to absorbance above the tissue and venous background and primarily reflects arteriolar hemoglobin absorbance (Wright, Lewander and Woolf 1999).

The original use and applications of oximetry to measure the saturation of hemoglobin oxygen in blood spread quickly to the medical field. Before the pulse oximeter was introduced to the medical field the hemoglobin–oxygen saturation measurement was done through arterial blood gas analysis, a slow, expensive, and painful diagnostic method to detect hypoxemia (Witting and Lueck 2001).

The invention of the modern pulse oximeter has caused a decrease in the use of arterial blood gas analysis; though this procedure is still used in the medical setting when there is suspicion of hypoxemia or hypercapnia. During hypercapnia, the pulse oximeter is not able to detect hypoventilation or high levels of arterial carbon dioxide (CO_2) on patients breathing supplemental oxygen (O_2). Hypoxemia is generally defined as: hemoglobin oxygen saturation of less than 70 mm of mercury ($PaO_2 < 70$ mm Hg) and hypercapnia as carbon dioxide-hemoglobin saturation of more than 50 mm of mercury ($PaCO_2 > 50$ mm Hg) when the readings are taken at sea level (Witting and Lueck 2001).

Physiology of respiration; the cardiac cycle; hypoxia; and pulse oximetry

The heart, respiratory, and circulatory systems work together in the delivery of gasses in and out of the human body. Both the heart and the lungs function through automatic rhythmic cell processes. The rhythmic system in the heart is driven by a specialized group of cells called the pacemaker, which fire up an action potential through its cells' membranes in between heart beats. In other words, they are the determinants of the heart rate. However, there are no analogous cells or structures known that trigger the rhythmic action of respiration. We know that respiration happens because of repetitive nerve impulses coming from the brain that trigger muscle contraction of the thoracic muscles and the neck (Saladin 2012). The primary function of the respiratory system is to obtain oxygen (O_2) through inspiration or inhalation for use by cells in the body and expiration or exhalation of carbon dioxide (CO_2) that cells produce as a product of cellular respiration. These two actions make a complete respiratory cycle. Oxygenation in the body occurs as oxygen enters the respiratory system reaching the alveolar sacs in the lungs that connect to capillaries and where gas exchange of incoming oxygen and outgoing CO_2 takes place by diffusion. Incoming oxygen leaves the lungs through associated vessels (pulmonary veins) and reaches the left ventricle and left atrium of the heart. As oxygenated blood passes through the heart, it is pumped through the aorta and distributed to tributary arteries feeding both the upper and lower parts of the body in what is called systemic circulation. Oxygenated blood reaches every organ in the body, unloading oxygen used during cellular metabolism and loading CO_2, a product of cellular respiration. Conversely, deoxygenated blood (oxygen-poor, but rich in carbon dioxide) returns to the heart via the venous system. Once deoxygenated blood enters the heart though the right ventricle and right atrium, it leaves via pulmonary circulation involving the pulmonary trunk, which branches into blood vessels that end in the lungs, and ultimately reach the alveolar sacs where gas exchange takes place.

Every constituent of the cardiac cycle and respiratory system is designed for a specific purpose. For instance, arteries and veins are different anatomically; on one hand, pulmonary arteries, which carry de-oxygenated blood, have thin distensible walls with less elastic tissue than systemic arteries. This fact plays an important role for the entire process of respiration. The implications of these factors are that blood flows more slowly through the pulmonary capillaries, allowing more time for gas exchange. Pulmonary veins have a blood pressure of 25/10 and a capillary hydrostatic pressure of approximately 10 mm Hg (mercury) in pulmonary circulation. This is a low blood pressure when compared to capillary systemic circulation, which is on average 17 mm Hg. Blood may back up in the pulmonary circulation system causing a condition called hypoxia (Saladin 2012).

Hypoxia is the deficiency of usable oxygen or the inability to take advantage of the oxygen that is present in the body. Hypoxia may vary from subtle to deadly (Furgang 2012) and may be caused by: strenuous physical activity; increase in atmospheric pressure and high emotional arousal, among other factors. Later in this article, I illustrate how some of our research participants in the Brooklyn College study experienced this respiratory condition, during high levels of stress and emerging emotions, as they presented and discussed sensitive and controversial sociocultural topics in the classroom. The site of gas exchange in the lungs or alveolar sacs measure approximately 0.2–0.5 mm in diameter. These pouches are covered 95 % by thin squamous epithelial cells. Again, the design of the cells allow for rapid gas diffusion between air and blood. The other 5 % of the epithelial cells are cuboidal epithelial cells whose function is to repair damaged alveolar epithelium and secretion of a mixture of phospholipids and a protein that coats the alveoli and small bronchi and prevents them from collapsing as one inhales. Other cells called alveolar macrophages serve as a barrier for dust particles and opportunistic bacteria that may be pathogenic.

It is important to mention that there are different "species" of hemoglobin. Also, respiration can take different forms according to the species of hemoglobin present in the circulatory system. The measurement of one hemoglobin species by pulse oximetry can be affected by the presence of any abnormal levels of any other hemoglobin species (Feiner and Bickler 2010). Some of the abnormal respiratory and oxygen saturation conditions in the blood of some of our class participants may have been mediated by the presence of any of these types of hemoglobin. Even though, we do not have the blood composition of every one of our participants in the study; we know that certain hypoxic conditions due to genetic predispositions in certain races may contribute to respiratory and circulatory disorders. In the Brooklyn College class we had a diverse group of participants. The class included individuals of Latina, Asian, African American, and White descent. It is possible that some of our participants had any of the types of blood mentioned here.

1. Deoxyhemoglobin (HHb): hemoglobin with no oxygen bound to it.
2. Oxyhemoglobin (HbO_2): one or more molecules of oxygen attached to hemoglobin.
3. Carbaminohemoglobin ($HbCO_2$): combinations of 5 % CO_2 bound to amino groups of plasma proteins and hemoglobin.

There are also several muscles involved during the cycle of respiration. It is not just restricted to the diaphragm. During inspiration a group of muscles in the neck, the sternocleidomastoid elevates the sternum and the scalene elevates ribs 1 and 2. The *internal intercostals,* which are located right below the ribs, elevate ribs 2–12 and widen the thoracic cavity, while the *pectoralis minor*, right below the chest, elevates ribs 3–5. The intercartilaginous part of the *internal intercostals* helps elevate the ribs and the diaphragm descends and causes an increase in depth of the thoracic cavity. Conversely, during forced expiration, the *internal intercostals* depresses ribs 1–11, narrowing the thoracic cavity; the diaphragm ascends and reduces the depth of the thoracic cavity; the *rectus abdominis* and the *external abdominal oblique* located in the abdomen depresses the lower ribs and pushes the diaphragm upward by compressing the abdominal organs (Saladin 2012). Of course all these structures, blood vessels, and muscles come together to bring about respiration through orders of the command centers in the brain. Three pairs of respiratory centers in the brainstem, specifically in the medulla oblongata and the pons control unconscious or automatic breathing.

These centers issue nerve signals that travel through the spinal cord and the phrenic nerves to the diaphragm muscle and intercostal nerves to the *internal intercostals* muscles. The contraction of these muscles causes expansion of the rib cage and inspiration (Saladin 2012). As we can see there is a connection between several systems that bring about the process of respiration. A very important aspect of respiration is how our brain provides feedback to the muscles and systems mentioned earlier to adjust to breathing the right amount of oxygen needed by the tissues in our bodies. This aspect of our physiology becomes crucial when we are experiencing hypoxic episodes, because we can opt to practice breathing meditation as an intervention therapy. Studies on breathing meditation, suggest that by executing this exercise, we can train the way our brain recognizes certain signals that may be detrimental to our wellbeing. The same way we have the capacity to adjust our brains to recognize situations, we can also adjust our brains to respond to situations. In our study, we asked participants to practice breathing meditation as a high-grade intervention to the hypoxic levels some participants were experiencing during specific stressful situations. Our participants were able to bring their oxygen saturation to a normal level, at least for a while, after their breathing meditation exercises.

Special conditions and respiratory deficiencies

The pons and the medulla are the respiratory centers in the brain that receive feedback from different areas of the nervous system, consequently they respond to physiological needs of the body. For instance, anxiety may prompt overwhelming hyperventilation. This condition is characterized by the expelling of CO_2 from the body at a rate faster than tissues produce it. This process yields a drop in the levels of carbon dioxide in the blood and an increase in its pH, which in turn causes cerebral arteries to constrict, resulting in a reduction of cerebral perfusion and causing dizziness or fainting. Hyperventilation is a controllable process that can be stabilized by rebreathing the expired CO_2 from a paper bag (Saladin 2012). During hypoxia systemic arteries dilate in response to local hypoxia and improve tissue perfusion. Conversely, pulmonary arteries constrict and not enough carbon dioxide reaches the lungs (Saladin 2012).

A more in-depth study of oxygen deficiencies in the group of participants we analyzed in this study, may provide relevant information on possible factors that could have mediated the pulse oximeter output obtained during data collecting. Some of the student teachers in our research seemed to have experienced inadequate pulmonary gas exchange during their coteaching experience that is consistent with hypoxemic hypoxia. The following are conditions that may cause hypoxia, yet they are not necessarily representative of the hypoxic conditions experienced by our students. Carbon monoxide has greater affinity with hemoglobin than oxygen does. When carbon monoxide and oxygen are present in the same space at the same time, carbon monoxide outcompetes oxygen, leaving it unable to bind to the heme group in hemoglobin; this is what is known as carbon monoxide poisoning. We also know that cigarettes are a source of carbon monoxide and cyanide. We are aware that some of our research participants smoke cigarettes. Although we are not certain of the factors that caused hypoxic events in our students, it is significant to mention some of the possible sources and conditions that may have prompted or exacerbated hypoxic episodes. Exposure to substances such as carbon monoxide and cyanide causes loss of elasticity in the alveoli, where gas exchange of oxygen and carbon dioxide occurs. A few of our participants in the study are of African American descent. A condition that is known to prevail in this ethnic group is sickle cell anemia, which results from the inability of blood to carry adequate oxygen to tissues. This condition is characterized by sickle shaped red blood cells and their inability to carry 4 molecules of oxygen to tissues. Histotoxic hypoxia, is an acute condition, usually caused by a toxic compound that inhibits tissues from using oxygen, an example of that is cyanide poisoning and its effects on cellular respiration (Saladin 2012). Methemoglobinemia refers to the oxidation of ferrous iron (Fe^{++}) to ferric iron (Fe^{+++}) within the hemoglobin molecule (oxidation of a molecule refers to the losing of an electron). Oxidation impairs hemoglobin from carrying oxygen and CO_2, leading to tissue hypoxia and ultimately death. This condition may arise from genetic, dietary, exposure to an oxidizing agent and sometimes from unknown causes (Wright, Lewander and Woolf 1999).

Other respiratory system disorders include: *apnea*, which is characterized by the cessation of one or more breaths; dyspnea, referred to as gasping breathing, or shortness of breath; *hyperpnoea*, is the increased rate and depth of breathing in response to exercise or pain; *hypoventilation*, is reduced pulmonary ventilation, in this case there is an increase in the level of carbon dioxide in the blood, and it is not expelled rapidly enough in comparison to the rate it is produced. *Kussmaul* respiration, is rapid breathing, usually induced by diabetes mellitus; *orthopnea*, is *dyspnea* when a person is lying down, usually occurs in heart failure, asthma and emphysema; *Respiratory arrest*, is the permanent cessation of breathing. *Tachypnea* is characterized by accelerated respiration.

Carboxyhemoglobin (HbCO) is a combination of carbon monoxide and hemoglobin. The compound is formed when carbon monoxide (CO) is inhaled through cigarette smoking, inhaling engine exhaust and fumes from furnaces and space heaters. CO has greater affinity with hemoglobin than oxygen does, because it can bind to the ferrous ion of hemoglobin 210 times as tightly as oxygen. For this reason when CO is available for binding it makes haemoglobin unavailable to oxygen, depriving tissues from getting oxygen for cellular metabolism and ultimately causing carboxyhemoglobinemia, also known as carbon monoxide poisoning or death (Saladin 2012).

Functioning of some pulse oximeter models may be affected by some of the physical and physiological factors mentioned. Although oximetry is a valuable tool in many settings by providing important physiological information in the moment, it is not to be used as a sole source to diagnose abnormal physical conditions. Some of the shortcomings of the instrument include sensitivity to motion and light. For instance, if the transmitted light is not detected by the detector accurately due to inappropriate strapping of the instrument to the area of the body selected for arterial pulsation reading, then the device may be susceptible to malfunction. Similarly, over exposure of the detector to ambient light may interfere with accurate readings. In addition, physiological factors such as decreased perfusion, hypotension, hypothermia and vasoconstriction can also affect pulse oximeter outputs. These conditions can lead to unsatisfactory signals that will trigger an inaccurate reading or no reading at all. Also, during high partial pressure of oxygen in arterial blood (PaO_2) there are very minor changes in oxygen-hemoglobin saturation levels (Callahan 2008.) This means that at lower levels of partial pressure of oxygen in arterial blood, small decreases in oxygen tension can lead to rapid decreases in oxygen saturation. For this reason a partial pressure of oxygen in arterial blood (PaO_2) of 75 mm Hg is correlated with 95 % oxygen saturation (SpO_2), and a PaO_2 of 50 % is correlated with 80 % SpO_2 (Callahan 2008).

Newer oximeter models are improving the nuances present in the older models through the use and application of new algorithms. Also, new technologies are adapting reflective light instead of absorbed light (Callahan 2008). The pulse oximeter is an affordable, painless, non-invasive instrument that can provide important physiological information to clinicians, pilots, educators, or any person that wants to have a sense of his/her physiological wellbeing. In the next section, I describe how oximeter outputs in some of the participants of our research at Brooklyn College, may have been mediated by internal body and exogenous conditions. Although further tests would need to be performed to know the exact culprit facilitating the abnormal pulse oximeter measures of our participants, we could say that it may be appropriate for them to look further into these breathing irregularities obtained during their coteaching experience.

Oximetry: tales from the field—research participant experience and intervention

In this segment I present the application of oximetry in a science education class context. The participants in this research were in-service and pre-service teachers taking a class on the history and philosophy of science education. Oximetry is utilized as a reflexive tool for the detection of physiological expression of emotions. I further look at the implications of becoming aware of emotions and how they can affect our wellbeing and our decision to remain in the field of education for a short or a long period of time.

I think this type of research has remarkable implications for present and future educators. Perhaps, incorporating intervention approaches to teaching and learning such as the use of oximeter while teaching can shed new light about the ongoing high rate of attrition for New York City and other Boards of Education across the United States. Hundreds of teachers enter the field every year and a large number of them quit within the first 3 years of entering the job. Many factors seem to affect their decision to look for other sources of employment that are more fulfilling and less stressful. One of the many reasons of teacher attrition is not being able to deal with the high accountability for the success and failure of students by administration. Such responsibility produces an incommensurable pressure that can be counter-productive to the wellbeing of teachers, affecting their effectiveness as teachers. In addition, if teachers have pre-conditions to certain medical disorders, these can be exacerbated by the demands of the job and what teachers deal with in the classroom on an everyday basis. Using the oximeter as an intervention device during the arousal of intense emotions in the classroom can be a powerful instrument for the monitoring of emotions, awareness and mediation to ameliorate emotional fluctuations and maintain a less stressful outlook about arising situations. Here, I describe two examples involving student teachers from the Brooklyn College study who wore an oximeter as they cotaught in the spring of 2012. To have a better idea of the examples presented here, let me note that the normal percentage of oxygen saturation (SpO_2) is between 92 and 100 % (Furgang 2012).

Case 1: What is going on with Sofia?

The first student teacher (Sofia) was coteaching with another two student teachers for the first time when they presented the topic of the philosophy of American schooling on week three of the semester. Sofia appeared to be nervous since the beginning of the presentation. She was wearing an oximeter during her first presentation and her heart rate readings started at 100 bpm, which are still normal, since a normal heart rate at rest is between 60 and 100 bpm. On the other hand, her oxygen saturation (SpO_2) in the blood was at a low 90. Figure 1 shows the output from the software associated with the oximeter, as it was displayed on the computer screen.

During her presentation, Sofia tried avoiding eye contact with the audience; she appeared to have a rapid chest rise and fall, as well as a shallow breathing pattern. Sofia's voice was quivering and 30 min into the presentation her SpO_2 dropped to 74 %, which is a very dangerous low level, and her heart rate became less elevated and dropped to 92 bpm. The oximeter output continued at this level for approximately 5 more minutes.

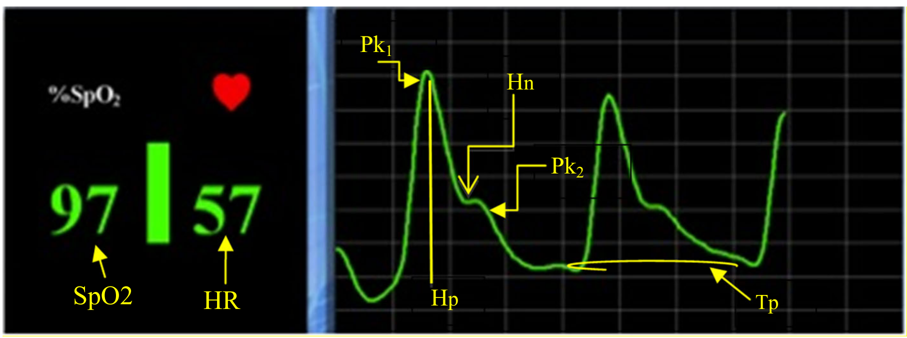

Fig. 1 Sofia's oximetry output of oxygen saturation and heart rate. SpO_2—oxygen saturation, HR—heart rate, Pk_1—peak 1, Pk_2—peak 2, Hp—pulse amplitude from the base to maximum during cycle, Tp—total pulse duration, Hn—distance from baseline to notch minimum; this small dip in the curve coincides with the aortic valve closure during systole

One of the researchers noticed the unusual readings that Sofia's oximeter was sending to the computer screen, so she decided to approach Sofia and asked her to take deep breaths. After a few minutes of breathing intervention, Sofia's SpO_2 started increasing and oscillated between 78, 85 and 87 % and remained at that level after post presentation. Sofia's heart rate reading oscillated between 80 and 111 bpm. These fluctuations in the output coincided with the times when the assigned articles for that night's topic were discussed. The discussion topics were on corporal punishment in different educational systems, as well as other forms of violence besides physical. Although Sophia's heart beat at rest presented some variation, we were not too concerned as much as we were about her SpO_2 outputs. Her low SpO_2 levels may have been triggered by nervousness and being sensitive to the topics presented and discussed. Sofia's SpO_2 levels were way below what they were under normal environmental conditions. They were also the lowest output readings among all class participants. As a result of these concerning oximeter outputs, Sofia decided to be pro-active about her health and obtained a pulse oximeter to monitor her heart rate and SpO_2 more often. Sofia also started practicing some of the interventions introduced in the class, such as mindfulness, radical listening, and breathing meditation exercises, and she continued the practice for the remainder of the semester.

During Sofia's second presentation on the topic of evolution, during week twelve of the semester; we observed a pulse oximeter output with a greater heart rate fluctuation (91–127 bpm) than what we had observed during her first presentation on week three. Sofia's heart rate towards the end of the evolution class was 76 bpm, which is normal compared to standard heart rate readings. However, her oxygen saturation (SpO_2) levels remained low, below the minimum threshold of 92 % for most of her presentation. Her range was between 84 and 99 %, yet there is a point that her oxygen saturation dropped to 79 %. These readings seem to indicate that she was experiencing a certain level of hypoxia or that she was experiencing an unusual respiratory/circulatory condition. My educational background is not in the medical field; for that reason I do not imply or suggest that Sofia has a health problem based on the oximeter data obtained in this research. Nonetheless, I strongly believe that the use of the oximeter in any situation can provide useful feedback on the physiological state of emotions. Having the opportunity to become aware of our emotions and its implications with our wellbeing through the use of this simple instrument can be beneficial when used as an intervention tool during interactions with others.

Sofia's unusual SpO_2 oximeter readings deviated greatly from the standard percentages that are considered normal in healthy individuals. Whether Sofia was nervous about presenting in front of an audience or she was upset about the controversial topics being discussed, it is evident that her emotions were running high and were affecting her physiological state. Although, her SpO_2 output was still below the minimum threshold of 92 %, Sofia's oximeter output during her second presentation was a few points above her pulse oximeter output when compared to the first presentation at the beginning of the semester. This is reflected in the increase in the 79 % SpO_2 compared to her lowest 74 % SpO_2 output during the first semester presentation. Some factors such as being more aware of her physiology as she wore the oximeter and monitoring it more often; the practice of breathing meditation since it was introduced to the entire class after her first presentation may have mediated the small improvement in her oxygen levels and heart rate. The pulse oximeter output was sent to a computer monitor through blue tooth technology. When we noticed that Sofia's heart rate and SpO_2 were abnormal, we approached her and asked her to practice breathing meditation exercises to see if she could get her heart rate, heart beat, and oxygen saturation to more comfortable levels. The practice of mindfulness, radical listening, and other intervention concepts used throughout the semester, may have helped

Sofia to mediate her emotions and become aware of her physiological output using the oximeter.

Physiology of a dream

Louise, our second student teacher, had a low 85 % SpO_2 output during her first class presentation compared to what is considered a normal SpO_2 output (92–98 %) for healthy adults. The topic she presented on "race and education" was not only controversial, but the mood in the class felt inhibited and there was reluctance from the majority of the participants in the class to contribute to the discussion. As a side note – the demographics of the class were diverse. The class was composed of students of Latino, Asian, White, and Black backgrounds from the United States and from various Caribbean Islands. Louise's SpO_2 pulse oximeter output ranged between 100–78 % for the majority of the class session, remaining mostly between high 80 and low 90 % outputs. There is an important spike in the curve regarding Louise's SpO_2 as the class formed groups to discuss the overrepresentation of minorities in special education and about distribution of resources. Louise's SpO_2 reached a low of 72 %, which is an outstanding 20-point difference below the normal for healthy adults! On the other hand, Louise's heart rate started with a reading of 103 as the coteachers addressed the class. One of our researchers talked to Louise about practicing breathing meditation. Her heart rate dropped from 103 to 91 bpm. However, as soon as Louise continued with the presentation, her heart rate jumped back to 109 and 115 bpm, eventually reaching 132 bpm. Louise's heart rate ranged from 98–137 during her coteaching presentation. Yet, her heart rate remained mainly above 130 bpm for most of the class period. Louise's breathing patterns seemed to change as well as her tone of voice, when she introduced the story of nine African American students involved in the desegregation of Little Rock Central High School. During this part of the presentation, Louise's heart rate looked like a rollercoaster. It dropped from 111 to 106 bpm, then to 96 bpm. It jumped back again to 114 bpm, followed by 120 bpm and then back down to 102 bpm. After she finished her presentation her heart rate started falling from 115 to 111, 109 bpm and below 100 bpm.

Louise's second coteaching presentation was on "philosophy of scientific progress." During this class she wore an oximeter to measure her heart rate and SpO_2 as she did for her first class presentation. Her heart rate started with a 98-103 bpm output. An interesting phenomenon occurred during this presentation, in that Louise and her co-presenter were in synchrony the majority of the time in terms of their heart rate and for most of the presentation it remained below 120 bpm. During a discussion on indigenous knowledge and science, Louise shared a story of her childhood in Haiti and growing up with her grandmother. In this moment, Louise's heart rate jumped to 161 and later dropped to 61 bpm. Her SpO_2 was below 92 %, and fluctuated between 82 and 88 %. When we brought these events to her attention, she responded: "I stop breathing to focus."

The 161 heart rate spike in the curve raised a red flag for us and when asked about how she felt about her grandmother after class in our cogenerative dialogue, she said: "I get so emotional when I talk about her." "She died by heart attack in her sleep—December, I still get too emotional around that time, 1995. We slept in the same room. It was a heartbreaking experience." As Louise told her story, we could see her emotions spilling out, as if there was suddenly an overflow of restrained emotions letting lose. Her bottom lip was quivering and she said: "I am holding back tears." Louise continued, "She didn't know how to read and write. On the island education wasn't for women. Women had to take care of men and do their chores. The grandmother started school at 45; this is when she learned to read and write. Louise: she always said: "The best thing to do is go to school." I didn't realize then that she was my first exposure to science. I never got sick with her (I only got my shots prior to coming here. I never went to the doctor." "She took care of me, and she knew what to make to keep me healthy. She impacted my choice for science - I want to accomplish her dream." The dynamics of the topics discussed in the classroom coupled with the audience presented challenging moments for Louise. Her emotions took over her physiological functions and these were represented in the fluctuations of the outputs, both of her heart rate and the (SpO_2) amount of oxygen taken into the lungs for respiration. Louise is an African American student from Haiti. She is also a biology teacher assistant in a New York City Public school.

Possible implications of this research

Educational research where oximeter data is obtained in the moment in the classroom appears to be a practical and useful way to become aware of emotions and possible health conditions that we may not be aware of. Whether we are mindful or not of certain classroom situations, our approach to classroom issues can have implications that can easily affect our relationship with our students, as well as the way they perceive us and the world around them. From the educator's point of view, the experience of researching in one's own class can provide great insights on how students perceive knowledge presented through different lenses. It can also afford important understandings of social structures within the class, so that we, as educators, can adjust teaching and moderating strategies conducive of effective learning environments. Furthermore, because the educator himself/herself is a participant, the learning experience becomes transformative. When educators become aware of their own limitations and vulnerabilities, their axiologies can be transformed in many possible ways and possibly extend to transform students' views and behaviors in the classroom as well. In addition, using the oximeter in the classroom can provide important information to the educator about his/her overall wellness and prompt open dialogues with his/her students about the emotional climate experienced in class. In an article published by Tobin and Reynaldo Llena (Rey) (2010) cogenerative dialogue was used as an intervention and pedagogic tool in the science classroom. Llena, who was the teacher, had the following interaction with a female student (Cindy) as he entered the room where cogenerative dialogue was taking place:

Cindy: Hello, why you so cranky? Why you so cranky? Rey's response was slow paced, measured and emotional. He remarked, "I am sick for like since last week and the more the more people aggravate me, I become more sick" During his response Cindy made an effort to show empathy (Tobin and Llena 2010, p. 151). While emotional tension is often experienced in the classroom between students and teachers and among students. The possibilities for positive emotional compassion during class interaction are at the reach of everyone, if only we are willing to become aware of our emotions and those of our students. The story of Rey as a science teacher however ended there. Rey's personal physician advised him to discontinue his career as a teacher (Tobin and Llena 2012). Rey's symptoms of poor health, compounded with high stress levels, were taking a toll on his health and at that point it was the best decision he could make.

The oximeter can provide clues to the state of such emotional arousal. However, there are some limitations to the information we can obtain from an oximeter. One of them is that we are not able to obtain the levels of carbon dioxide saturation in the arteries at any time using the device. Having high levels of carbon dioxide in the blood can be a sign of something abnormal in the body. The oximeter should not be used as a sole diagnostic test for any respiratory or circulatory condition. In addition, one must take into account possible factors that affect pulse oximeter outputs, like moving the device while wearing it and not having it appropriately strapped to the wrist.

Schools are perhaps the second place and very often the one place that instills a significant social influence in a person's life. In schools, people acquire knowledge, academic and social skills that enable them to navigate in a world of competitive survival. Furthermore, today's schools seem at times to occupy niches where neoliberal ideologies based mostly on statistical measures of accomplishment, guide how we teach and learn. However, as teachers and as the people directly involved in the education of thousands of students, deal with numerous issues on a day-to-day basis that go beyond statistics and that influence our students and their perceptions of the world they experience. Even when we are to follow a set curriculum and prescribed pedagogy, knowledge is affected and constantly evolving by emotional output of class participants. In light of this, education for new generations of students and teachers should not be restricted to the prescribed curriculum. In the same way our classrooms are being updated with the latest technological gadgets, microcomputers and devices, we need to update our personal approach and the way we learn and teach in the classroom. Although I agree that much attention and resources must be invested in building a strong academic force, we must not depart from the idea that the success of building such social structures depends on the way we interact with each other. Our interactions are charged with positive and negative emotions that shape the way we perceive and respond to social phenomena. As individuals, we carry our convictions and idiosyncrasies wherever we go. Very often, we are not completely conscious that a simple word, response or gesture can impact students' own views; how students feel about the world around them; the place they have in it; and what they are capable of achieving. We go in the classroom to accomplish what we set out to do; teach a theory without really thinking of the implications and practicalities that such theory has on the people we are teaching. It is apparent that this new/old outdated approach to teaching and learning is not the most effective for all students and teachers. I often ask myself, why if everything else around us is changing, are we still following teaching and learning methods that we used two hundred years ago? Teachers and students are much more than statistics. Teaching and learning involve not only instructing and receiving information. They involve personal interactions where human emotions are stimulated and expressed through different perspectives and dialogue. It is because of the great influence we exert on individuals that we, as educators, must review, revise and transform our pedagogy where needed. In the sciences especially, there is an almost dogmatic way of thinking that permeates the minds of those that enter the field and that must be passed along new generations of scientific thinking. Nevertheless, in my opinion there is no reason why we must depart from what makes us unique among creatures, which is the ability to reason, have compassion and sensibility to the emotions of others as they execute their agency for what they believe. Crucial factors that involved radical listening, compassion, and social intuition (Davidson and Begley 2012) in general are often missing in the classroom. I often talk to students and peers about their interactions with others in the science classroom or in the science field, they express dissatisfaction about the science culture in terms of insensibility. Their accounts regarding the hostility they experienced in science classes reminds me of the way some of the most brilliant professors I had in college would talk to us. They would answer some of our questions with a touch of arrogance and sarcasm. It feels very often as if becoming a scientist was reserved for only a few privileged individuals; and that one of the conditions for becoming one was to have a cold and superficial attitude towards the rest of the world. Similarly, I remember some of my classmates feeling frustrated as a result of the cold and unwelcoming attitude they experienced from some of their science professors. Very often, this was the reason why students gave up their educational goals in science, making career moves to places where they felt welcome. On the other hand, teachers tend to experience negative emotions, such as frustration, anger, and disappointment in response to students' poor academic performance (Ritchie, Tobin, Sandhu, Sandhu, Henderson and Roth 2013). A transformation of the world that surrounds us will not take place; unless we take the first step to enable change to happen. Educational research is rarely done inside the researcher's own practice. There are even regulations in certain schools that prohibit teachers doing research as part of their own praxis. While the rationale behind Institutional Review Board regulations are based on the avoidance of biases and conflict of interest, action research and self-study practices can have a powerful and transformative effect in the science classroom. For Alexakos and me, there was a profound transformation in the way we think of how we talk to our students, how we listen to our students, and how we deal with emotions, as students and we express them during controversial and sensitive class discussions. In a traditional class, students' input is not often taken into account as part of the learning process. It is not enough anymore to collect data in schools and make published research available to educators. The traditional way of educational research leaves out teachers and learners and their vibrant contributions to formulating research questions and methods to the field of research education. In our Brooklyn College classes, we tried listening to and learning from our students and from their interactions with one another. It was by fostering this type of environment that we could have a productive learning experience. The development of new teaching and pedagogical methods, such as those that use instruments like an oximeter, are necessary to improve and create an educational infrastructure that is highly effective for students and teachers. When we consider learning science through multiple perspectives, we are opening new avenues of understanding about differences in our points of view. It is by grounding our teaching practice in conjunction with educational research that we have the potential to observe the areas where we need to improve.

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Olga Calderón is an assistant professor of biology and microbiology in The Natural Sciences Department at LaGuardia Community College of the City University of New York. Her pedagogic research focuses on the role of emotions in the classroom and the impact of wellness approaches such as mindfulness and breathing meditation as interventions to improve teaching and learning.