CLIMATE MONITORING USING AN ARDUINO-BASED MOBILE WEATHER STATION AND OPEN-SOURCE CODES

Mohundranathsingh Ujoodha
Anand Pultoo
Avinash Oojorah

ABSTRACT

Climate monitoring has become an essential skill within the Mauritian community in face of the increasing number of meteorological hazards to which the island is subjected. The tourism sector, which is one of the main pillar of the Mauritian economy, is intricately connected to climate events and many inhabitants livelihood may be at stake if an ignorant eye is casted over environmental disruptions. Hence, the need to increase awareness concerning climate change through experiential educational strategies has emerged as a crucial requirement in schools. This paper demonstrates how the use of a low-cost Arduino based mobile weather station can enable learners to follow up with climate change within their immediate environment and thereby contribute in decision-making processes. Moreover, aspects of the island's climate were investigated through the collection of various metrics such as indoor/outdoor temperatures, humidity, atmospheric pressure, altitude, dew point temperature, and heat index. Learners had a greater appetite to study climate change using the mobile weather station as well as better understand the interconnectedness between pressure and altitude, dew formation and temperature, real feel (heat index), and humidity. Our findings offer insights for schools and policy makers to include the use of robotics in classrooms so that learners may follow up with climate change within their immediate environment.

Keywords: Climate monitoring, Arduino, Mobile weather station

INTRODUCTION

Mauritius, a tropical island in the Indian Ocean, is ranked 16th amongst the highest disaster risk countries with respect to climate change according to the 2018 World Risk Report (Heintze et al., 2018). The country is very vulnerable to climate ailments ranging from tropical cyclones, flash floods, droughts, beach erosion, and abnormal temperature patterns. Climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) as "*a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer*" (IPCC, 2007, p 30).

There are a number of international global programmes, which are specifically geared towards sensitizing scholars to the impending dangers of keeping a blind eye on climate metrics. The Globe Program launched in 1995 has a dedicated mission to improve Earth's environment at local, regional, and global scales as well as promote scientific discovery (Globe, 2020). In so doing, most climate change projects involve some elements of technology since a number of sensors are now available at reasonable costs to measure parameters such as humidity, temperature, and atmospheric pressure, which were traditionally recorded with costly instruments.

The effects of humidity and temperature on climate change have been extensively documented during the previous decades. Barecca (2012) found that these two factors have significant health impacts and are important determinants of mortality rates. Jigyasu (2019) pointed out that sandstones become increasingly unstable to humidity changes and, coupled with an increase in sea level and flashflood, are more prone to cracks in historic buildings as well as tropical construction basement. Furthermore, 76% of all meteorological events between 1988 and 2007 were hydrological in nature and accounted for 45% deaths and 79% economic losses due to environmental hazards (UN-ISDR, 2008).

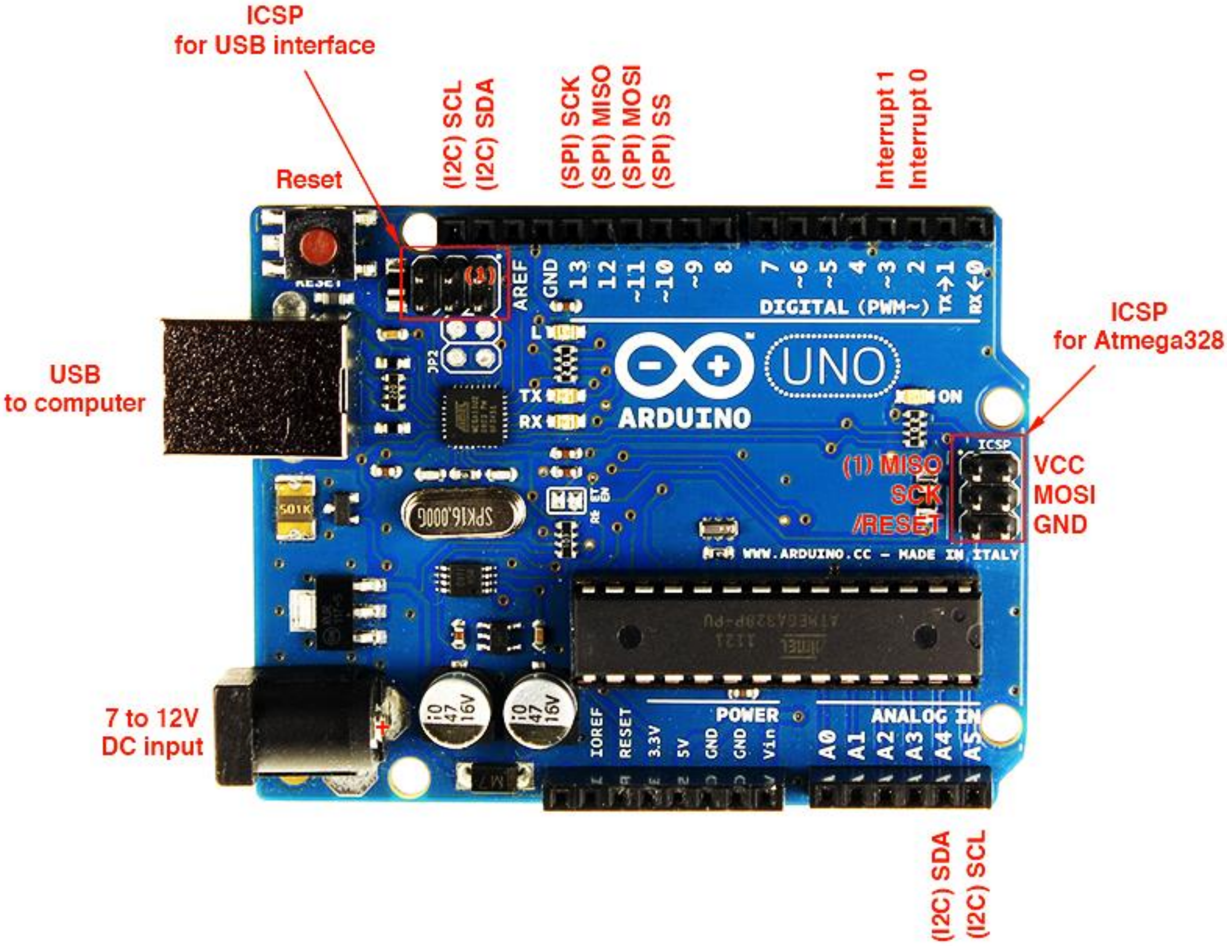
Arduino is a physical computing tool with an open-source electronics platform based on user-friendly hardware and software for creating different projects and applications (Zaini et al., 2020). A physical computing approach takes computational concepts "out of the screen" and into the real world so that student can interact with them (Richard, 2008). Mohammed El-Abd (2017) demonstrated that Arduino could be a very promising educational platform in embedded engineering. It can be utilized to cover many of the core units under the embedded systems knowledge area in computer engineering. Moreover, it can be used to overcome a number of challenges facing embedded education nowadays.

The need to teach learners how to keep track of weather changes within their immediate environment is therefore being addressed in this paper. A constructive learner-centered maker-based activities seemed more appropriate for creativity projects and were selected as the main instructional method (McKay & Glazewski, 2016). Thirty students of Grade 9, aged between 12-13 years old took part in this research project and were initiated to electronics and robotics. They were also introduced to the Arduino board, Arduino IDE, coding, Open-Source codes, sensors, electronic display panels, soldering, circuit diagram, and troubleshooting.

LITERATURE REVIEW

Invented in Italy in 2005, the Arduino platform is an open-source electronics platform designed to be used through an easy plug and play model. Besides being of low cost, cross-platform and highly versatile, the Arduino circuit board has attracted many enthusiastic users across the planet ranging from instructors, learners to hobbyists. It may be programmed through a range of programming software, the most common one being the Arduino IDE (Integrated Development Environment) which is used to write and upload codes on the hardware. There are a number of Arduino boards available on the market, which have been constructed to meet the demands of different users and environments. For example, at the entry-level, the Arduino Uno board may be crafted with an Atmega 328 processor, 6 Analogue pins, 14 Digital pins, 1 USB port, and 32 KB Flash memory. For higher ends projects, the Arduino Mega 2560 with greater connectivity pins and memory is greatly prized by university students. The portability of Arduino-based circuits is due to its 5V power supply, which can be readily provided by dry cells. Additionally, ‘shields’ are available to cater for specific uses and make circuit board manipulation effortless. For example, a Wi-Fi shield could enable the user to grant internet connectivity to the Arduino board and allow live data acquisitions.

Figure 1: Arduino UNO pinout diagram



ARDUINO IDE

The Arduino IDE consists of a basic integrated platform, which allows programmers to code in C or C++ language on a PC. It can run smoothly on Microsoft, Linux, and Mac OS X, which indeed enrol a larger community of users (Arduino.cc, 2018). The program codes that can be written on the Arduino IDE is referred to as a sketch and are ultimately fed to the Arduino board for electronic instructions. A closer look at the Arduino IDE shows that it consists of four main parts namely the Text editor, Message area, Text, and Console toolbar. The Text area is the space where a simplified version of the C++ language can be input. The message area, as is depicted by its name, informs the user about the debugging processes when exporting the codes to the Arduino board, and displays feedbacks after successful or unsuccessful code transfer processes. The console displays Text output from the Arduino IDE inclusive of the error codes found during debugging. Similarly, the Console Toolbar contains additional features such as the usual functions of file manipulations such as Open, Save, Verify and Upload but also includes additional utilities like the Serial Monitor, which enable the user to gather live data from sensors that are then displayed on the screen.

CODING

Coding along with computational thinking are considered as the prime skills that 21st Century that learners should develop to increase their employability opportunities. With the advent of globalisation, interconnectedness had revolutionized the need for increased digital proficiencies. Consequently, futuristic think tanks are anticipating that coding should be a core requirement in educational curricula as from primary schooling. However, the biggest issues are the development of analytical skills, systematic reasoning and creativity. Learning programming languages makes people think in a very different way, in an algorithmic manner, to use abstraction in order to understand complex systems, and to understand how these interconnect (Mishra & Yadav, 2013). Additionally, Pultoo et al. (2020) found that the learning of coding is enhanced when learners try to solve real-world problems with the use of electronic devices or participate in coding competitions with incrementally higher levels of complexity.

OPEN-SOURCE CODES

Open source is coined to a new movement for the dissemination of scholarly contents through the internet, overcoming barriers of timely delivery, cost and accessibility. It is believed that the evolution of open-source resource is embryonic to the internet boom and its full potential is yet to be fulfilled. As rightly postulated by Veletsianos (2016), emerging technologies may not always be new and are coined to terms like *not yetness, coming into being and unfulfilled potential.* MOOCs, OERs and Creative Commons licenses are all subsets of the Open Access movement which aims at rendering freedom of education to a maximum of users through free or minimal fee courses and materials. Siemens's (2005) concept of connectivism is very relevant to the explosive use of the social media whereby information is said to be constantly changing, that learning which takes place in distributed networks of people is based on diversity of opinion and where content and services are adaptable and responsive to the specific needs and goals of social media. Facebook, YouTube as well as Twitter are in a continuous process of upgrade and innovation since their inherent maximum potentials have not yet been reached (Couros, 2006).

SENSORS

Arduino was developed with the intent to provide an economical and trouble-free way for hobbyists, students and professionals to build devices that interact with their situation using sensors and actuators. This makes it appropriate for beginners to get started quickly. The Arduino UNO board has five analog pins ranging from A0 to A5. Analog sensors such as motion, light or temperature sensors can send analog signals to these pins, which would convert these values into digital ones via the microprocessor. There exist a number of sensors, which may be attached to the Arduino board namely the DHT 11 temperature sensor, BMP 280 pressure sensor or ADXL 335 acceleration sensor. The DHT 11 sensor is a capacitive humidity sensing digital temperature and humidity module is able to send digital output signals of temperature and humidity within a prescribed range (Manghnani et al., 2017).

ARDUINO-BASED MOBILE WEATHER STATION

The use of a mobile weather station in an educational setting has not been vigorously investigated in Mauritius. Although the island is continuously being subject to tropical cyclones, flash floods, droughts and flooding of coastal areas, the existing educational curriculum only incorporates the cognitive aspect of climate change. The absence of experiential activities in schools to study the evolution of climatic metrics such as temperature, humidity, and atmospheric pressure is a shortcoming for awareness building within the learners' community. For example, postulants of the agricultural community cannot rely on natural climatic conditions to grow their crops (Saranya et al., 2017) which, in extenso, implies that greater educational capacity building should be done in the society. Given that enhanced monitoring systems and adaptation strategies should be at the forefront of climate change mitigation policies (Jigyasu, 2019), it is indeed desirable to inculcate such skills in the younger minds such that they grow up in a 'new normal' set of values that would place environmental wellbeing at the core of their lives.

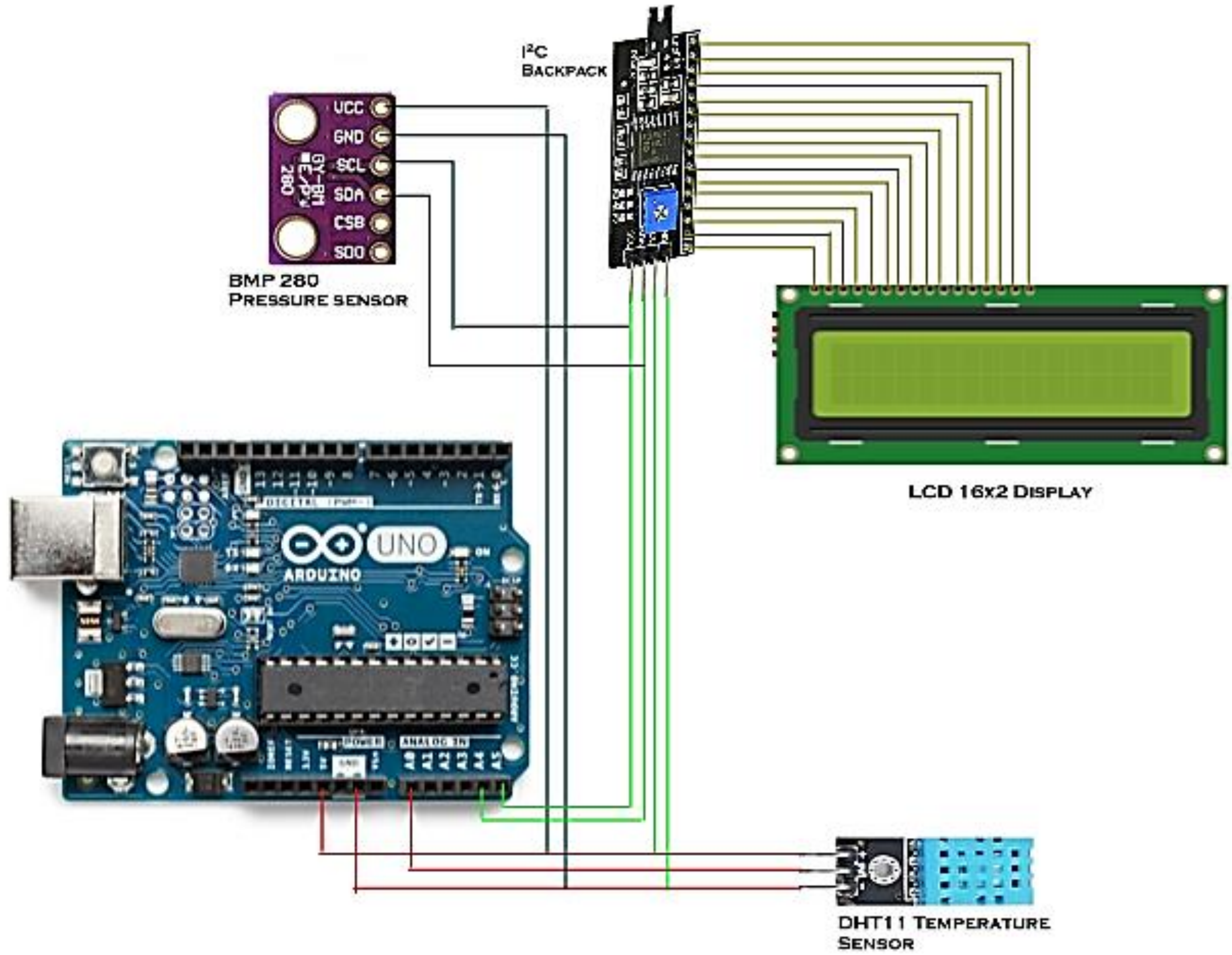
METHODOLOGY

The temperature and humidity monitoring system was developed using various components viz., Arduino Uno, DHT11 sensor, universal serial bus (USB) type B cable, adaptor, DC power jack, 9-V battery connector, 9-V DC battery, resistor, liquid-crystal display (LCD) screen, trimmer potentiometer, light-emitting diode (LED) bulbs, jumper wires, micro secure digital (SD) card module, printed circuit board (PCB), etc. The field-testing of the developed temperature and humidity monitoring system was done at several sites of the college grounds.

CIRCUIT DIAGRAM

The circuit diagram of the mobile weather station included an Arduino Uno board, DHT11 temperature sensor, BMP 280 pressure sensor, I2C backpack adaptor, and a 16x2 LCD dot matrix screen. The station was powered by a USB power bank or dry cells connected in series of 5-6V combined voltage. This power source was not only used to run the mainboard but also the temperature and pressure sensors, LCD screen, and I2C backpack adaptor. Care was taken to ensure that the sensors were supplied with a voltage of 5V from the energy pin of the Arduino as well as grounded with the GND terminals. The I2C LCD backpack adaptor, which contains a PCF8574 port-expander IC, was of great help to minimize the use of jumper wires to activate the LCD. After the codes were loaded on the Arduino board, records of temperature and humidity were collected from the DHT11 sensor and displayed on the LCD panel. The A0 Analogue pin was used to collect data for temperature and humidity whereas the SCL SDA pins were programmed to receive signals of pressure and altitude from the BMP280 sensor. The readings obtained from the BMP280 sensor were affixed via the LCD screen.

Figure 2: Mobile weather station circuit diagram

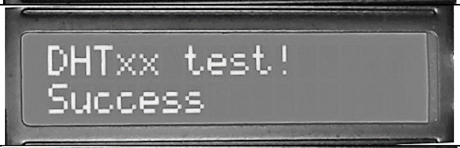


CODES FOR THE WEATHER STATION

The codes for the weather station were input in the Arduino IDE and involved several parts. The introductory codes of the program initialized the sensors, LCD display and various libraries that were to be used during data capture. Since the Arduino IDE contains an integrated system to upload and update the libraries, it was relatively easy to find the zipped libraries for Creative Commons sources. For example, the I2C backpack to LCD adaptor library was uploaded from the GitHub, an online software source code repository provided the required attributions to the author was included in the program's descriptions (Dalmaris, 2019). Test codes were included to verify the functioning of the DHT11 and BMP280 sensors before proceeding with activation of the digital and analogue pins.

Moreover, codes on various metrics were added to compute data for the mobile weather station. These included the calculation of the dew point temperature from readings of temperature and humidity attributed to the works of John Main (BMP, 2020). Some of the metrics such as 'Cloud Base', 'Heat Index' or 'Climate' were coded by students to reflect in situ climate conditions of the immediate environment. One of the important parameters that was recorded by the mobile station was the Heat Index, which is often regarded as of primary importance by the civil society and media broadcasters. Since Mauritius is found in the Indian Ocean, the increase in both temperature and humidity during summer can result in dangerous Heat Index values, which should warrant Warnings from the meteorological services and other Health and Safety organizations to protect livelihood as well as health. Our readings corroborated the fact that Heat Index Values greater than 45 could be recorded in Mauritius, should abnormal maximum temperatures of 38^{0}C be recorded at the peak of the summer period. Hazard texts such as "CAUTION: REMAIN INDOORS" were included in the codes of the Heat Index warning protocols.

Figure 3: Examples of LCD displays of the mobile weather station

Displays	Description
	Introductory screen of the mobile weather station
	Initial testing of the DHT11 temperature sensor. If the sensor is faulty, the message “Failed to read from DHT sensor” would be displayed.
	Initial testing of the BMP 280 pressure sensor. If the sensor is faulty, the message “Could not find a valid BMP280 sensor, check wiring!” would be displayed.
	Readings of Temperature (ºC) and Humidity (%) are read from the DHT11 sensor and shown on the LCD screen.
	The Real Feel (Heat Index) is read from the DHT11 sensor and displayed. The Dew Point Temperature is calculated using the dew point formula containing the temperature and humidity variables.
	The pressure and altitude are read from the BMP280 sensor and shown on the LCD panel.
	Sea Level pressure is computed by making allowance for the difference in altitude. The recording is in line with the prevailing Anti cyclonic weather at a barometric pressure of 1021 hPa.
	The Cloud base is calculated taking into consideration the temperature, humidity, dew point temperature, and height.
	Adjustment with altitude is done to obtain the Cloud Base at Sea Level
	Conditional formatting codes have been added to obtain this display. The Warning message is related to the computed value of Real Feel (Heat Index).

DATA COLLECTION

The mobile weather station was used to gather data for recording climate-related readings such as Temperature, Humidity, and Atmospheric pressure that, in turn, were utilized to compute values for Dew point Temperature, Altitude, Cloud Base and Heat Index. The Arduino kit was mounted on a handicraft basket so that the students could easily carry around to make recordings. A 6V power bank enabled an uninterrupted supply of electricity to the circuit and was strapped into the portable basket for easy charging.

Students of Grade 8 used the mobile weather station to test the reliability of the readings from the DHT11 and BMP280 sensors. The DHT11 sensor has an endorsed accuracy error of ± 2% for temperature and ±5% for humidity readings. The BMP280 has a registered pressure accuracy of ±1 hPa and ±1m from its altimeter readings. Although the BMP280 sensor can measure temperature with an accuracy of ±1.0 ^{o}C, the DHT11 sensor was used selected to collect the data for temperature since the computation of the dew point values required variables from the same electronic component.

Given that standardized tests of the sensors could not be done in lab settings, prior readings from the weather station were collected and matched with those from the Mauritius Meteorological Station (MMS, 2020). The data obtained were within the tolerance range of ±5 %, which can be considered as reliable for lower secondary school practice. At no point in time, disproportionate values of temperature, humidity, or pressure were obtained from the mobile weather station whilst taking readings within recommended rules of practice. It was noticed that readings under direct sunlight should be avoided since higher values of temperatures are obtained and that the Arduino kit should be rested for at least three minutes to ensure that stable values are obtained.

The school also received the visit of Meteorologists from the National Meteorological station. These experts recommended the use of a Stevenson screen to collect reliable outdoor data within the precinct of the school. Furthermore, they advised that other values can be collected to measure soil temperature, soil moisture, rainfall, wind speed and relative humidity. Students were made aware of other instruments that can be fabricated with the use of an Arduino board such as the electronic soil thermometer, rain gauge, mini anemometer and compact psychrometer. The recordings from these instruments are believed to be very relevant for the agricultural communities of the neighbouring villages. It is understood that the next phase of this scholastic research could take this direction and help pineapple planters and farmers to make informed decisions about the variety of seeds that they should use as well as for other agricultural practices.

RESULTS AND DISCUSSIONS

Students had the opportunity to take readings within the school area and use these values to understand the weather patterns in the village of Camp De Masque. As only one unit of the Mobile Weather Station was constructed, the Arduino kit be shared amongst learners so that they may follow up with climate changes within their home environment. A power bank was also attached to the mobile weather station to make the experience more adventurous. Learners from different villages were allowed to take possession of the mobile weather station and take recordings at home. The feedbacks were collected in class through group interviews and plenary discussions.

The learners compared their readings and came to the conclusion that:

1. temperatures tend to increase as they move towards sea level. The opposite was true as recordings were done higher inland. A difference of up to ±5 ^{o}C was observed as compared to the readings obtained at school. No scientific comparison was possible since the recordings were done at different times of the day and indoor/outdoor environment. However, students concluded that different villages may exhibit different temperatures due to geographical or other reasons.

2. the atmospheric pressure tends to increase during the transition periods of April and May. This was explained by the fact that anticyclones tend to build up at this time of the year. The increase in pressure was usually accompanied by episodes of sporadic rainfall and cold wind gusts in line with the approach of anticyclones.

3. during the approach of cyclone Diane around 25th January 2020, the barometric atmospheric pressure decreased below 1005 hPa. This was later explained in class as being the result of a pressure void in the eye of the cyclone.

4. mist formation happens during conditions of low temperature and high humidity. Actually, one student who lived in the higher inland area of Alma noted that regular dew development in his area was explained by the fact that morning temperatures tend to drop more than his peers. He confirmed that his village is perched in a hill like topography and unprotected from the cold southeast trade wind. This may explain the particular microclimate that is observed in his village both in summer and winter.

5. high humidity values and high temperatures at the pinnacle of summertime increase bodily discomfort. Students noticed that when the Real Feel (Heat Index) value of about 40 is recorded, the “High Discomfort” warning sign appear in the Mobile Weather Station. This was mostly the case when readings were taken in coastal area villages such as Flacq. Concurrently, students living on the higher ground did not record such high ‘Real Feel’ values apparently due to lower temperatures.

6. higher humidity is observed during cyclonic weather and rainfalls. Some students intelligently observed that their home ceramic floor tiles became wet due to condensation of the water vapour on the colder surface of the tile. The learners agreed that these extreme conditions happen when the percentage of humidity is greater than 88% with low temperatures and the absence of wind. They suggested that these conditions may be hazardous in case of glazed floor tiles and people with disabilities.

7. high humid conditions in Mauritius causes mold formation in organic matter. There was a general consensus that mold formation tends to propagate in higher inland villages due to a decrease in air circulation within closed spaces, lower temperatures and frequent rainfall events. Some learners went as far to suggest that the architecture of a house, particularly if it lacks window openings for sunrays and proper air ventilation could face chronic mold formation throughout the year. They agreed that mold formation can be a serious cause for concern for asthma patients and farmers. Several scholars stipulated that their parents, many of which are farmers, had to dispose of cargos of ginger, yam and taro harvests due to mold formation. Besides, students were able to extrapolate their knowledge on mold formation to explain the proliferation of fungus on leather items in closed shops during the Covid19 lockdown period.

8. concrete houses have a tendency to retain more heat and that tropical style houses must contain large verandas to allow for air ventilation and cooling. There was an agreement that wooden houses are more appropriate for tropical climate due to their insulating properties. Besides, one student noted that there was a difference of 1 ^{o}C between his first-floor temperature as compared to the ground floor both in summer and winter. Learners suggested that exposure to sun rays on the first-floor concrete roof may explain this phenomenon.

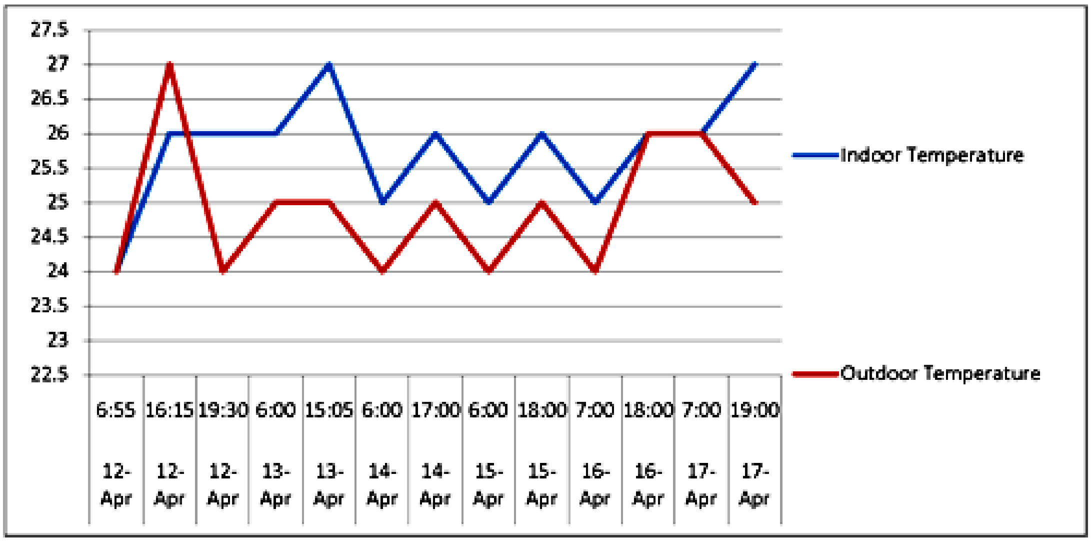
9. condensation underneath covered patios and glasshouses are due to high humid conditions as well as the difference in temperatures. Some learners stated that high humidity can be predicted during morning condensation of water droplets on the corrugated iron sheets in their greenhouses. These condensations tend to be less frequent during winter during to lower temperature differences.

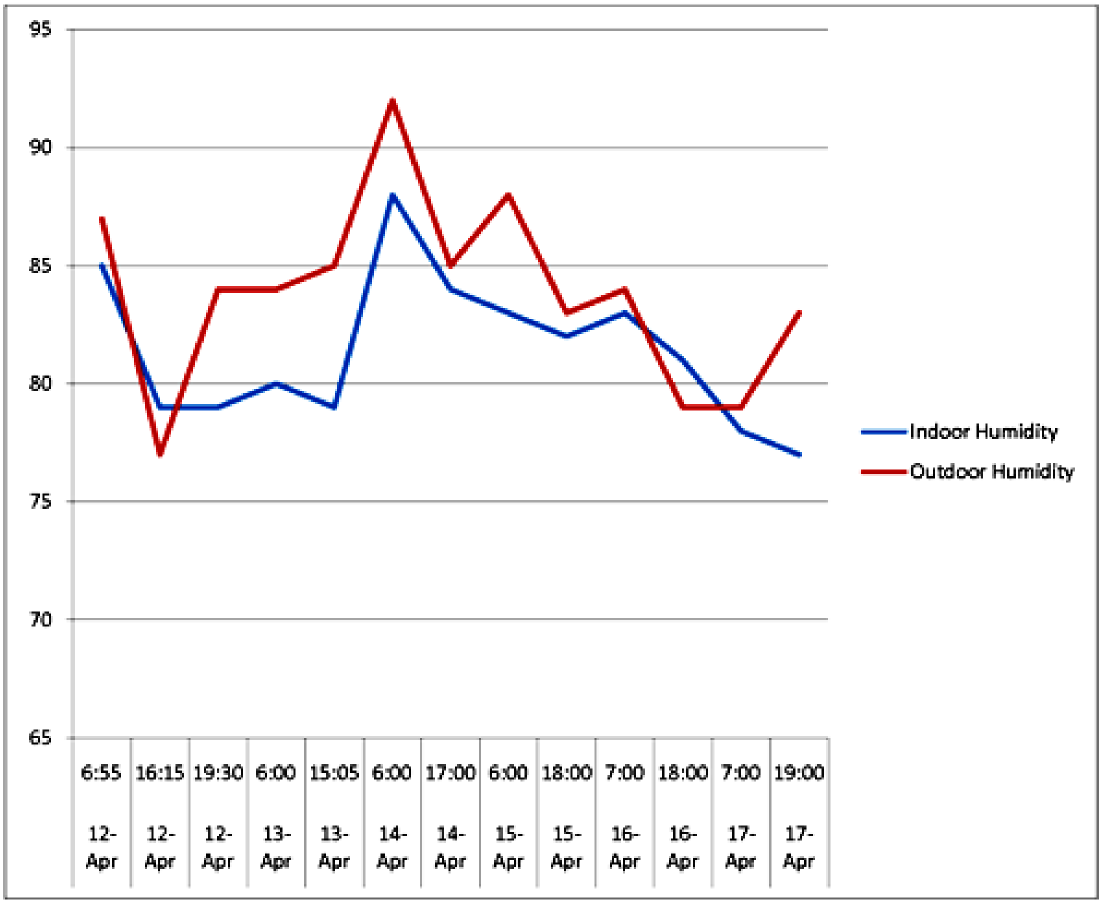
10. climate variability can only be observed during a long period of study. The pupils agreed that the use of the mobile weather station can be of great help not only to keep track of abnormal climate changes but also advise on various issues such as the warehousing of food, protection of electronic items against humidity and choice of residence for people with disabilities.

11. alarming readings of heat index greater than 45 could be recorded in Mauritius if temperatures of 38^{o}C start to peak during Summer periods. Learners attention were directed towards a recent report of the Meteorological services that it should not be a surprise if peak temperature in the hottest areas of the island rises in the vicinity of 38^{o}C. Coupled with high humidity, the heat index would flash in the red zone which means that some people may fall prey to heat-wave shock or similar.

Figure 4: Chart of indoor/outdoor temperature and humidity submitted by a student living in the village of Quartier Militaire, Mauritius

DHT11 Arduino Sensor. Site: Quartier militaire





CONCLUSION

The use of the mobile weather station in a school setting is in line with Kolb's experiential learning model whereby the learning process is done through experience (Kolbe, 1984). It is indeed a feat that the collection of data from costly Meteorological instruments has given way to more accessible inexpensive devices thanks to the invention of open-source hardware like Arduino. This paper has demonstrated that coding of an Arduino Uno board along with the DHT11, BMP280 sensors and 16x2 Liquid Crystal Display Panel can be easily achieved at school by lower secondary students. The use of Open-Source Codes has been of paramount importance to start the coding expedition and the research team believes that the teaching of rendering attributions through Creative Commons License should be given its due merit.

This study demonstrated that learning of climate change through the use of a mobile weather station stands out differently in contrast to the existing pedagogy used in Mauritian schools. The students were able to satisfy their curious minds by using Arduino sensors to take various readings. Amongst various investigations, students were able to observe in live settings how mist formation has a direct correlation with the dew point temperature. They also succeeded to suggest ideas about the materials that could be used to mitigate heat absorption following their readings in concrete houses. Indeed, these types of micro thinking are very supportive to the cause of science and can generate greater experimental interests in the learners' life.

Although the impact of climate change in Mauritius cannot be wholly reversed, the use of the mobile weather station can be extended to other Communities of Practice such as farmers, building contractors, health officers, and entrepreneurs. This would provide additional impetus to validate best practices in relation to ambient temperature, humidity, and pressure. The researchers also believe that the teaching of science in schools should include elements of Robotics that can sustain the fascination of the young generation of learners and pave the way to a more sustainable society.

Implications for practice or policy

- Policymakers should evaluate the strategy of infusing the learning of Robotics in schools to promote experiential learning.
- Stakeholders whose activities are affected by climate change should be empowered to use a mobile weather station.
- The use of Robotics as a measurement tool should be mastered by trainee Science educators to promote the Maker Movement in schools (Martinez, 2019).

REFERENCES

Arduino.cc. (2018). Arduino – Introduction. http://arduino.cc/en/Guide/Introduction.

Barreca, A. (2009), Climate Change, humidity and mortality rates in the United States, Tulane Economics Working Paper Series, Tulane University, 55 pp. http://repec.tulane.edu/RePEc/pdf/tul0906.pdf.

BMP. (2020). How to use the DHT22 and Arduino to Measure Humidity, Temperature, Dew Point and Heat Index. Best Microcontroller Projects. https://www.best-microcontroller-projects.com/dht22.html

Couros, A. (2006). Examining open (source) communities as networks of innovation: implications for the adoption of open thinking by teachers, University of Regina, Regina, SK, Canada.

Dalmaris, P. (2019). Arduino: a starting up guide for complete beginners, Tech Explorations.com, 67 pp.

El-Abd, M. (2017). A Review of Embedded Systems Education in the Arduino Age: Lessons Learned and Future Directions. *International Journal of Engineering Pedagogy*, 7 (2), 79-93. https://doi.org/10.3991/ijep.v7i2.6845

Glazewski, K.D. & McKay, C.S. (2016). Designing Maker-Based Instruction. In C M. Reigeluth, B. J. Beatty, & R. D Myers (Eds.), Instructional-Design Theories and Models, Volume IV (pp. 161-188). New York: Routledge.

Globe. (2020). The Globe program - A Worldwide Science and Education Program. https://www.globe.gov/about/overview.

Heintze, H., Kirch, L., Küppers, B., Mann, H., Mischo, F., Mucke, K., Pazdzierny, T., Prütz, R., Radtke, K., Strube, F., and Weller, D. (2018). World risk report. Bündnis Entwicklung Hilft and Ruhr University Bochum, 56 pp.

IPCC. (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R. K & Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Jigyasu, R. (2019). Managing cultural heritage in the face of climate change. *Journal of International Affairs*, 73 (1), 87-100.

Kolb, D. (1984). Experiential Learning: experience as the source of learning and development. Englewood Cliffs, NJ: Prentice Hall. p. 21

Manghnani, S., Chittampally, R. & Kasaram, P. (2017). Arduino Based Wireless System for Temperature and Humidity Monitoring. *International Conference on Emerging Trends in Engineering, Science and Management*, 521-528.

Martinez, S. (2019). The maker movement: A learning revolution. International Society for Technology in Education, (ISTE). https://www.iste.org/explore/In-the-classroom/The-maker-movement%3A-A-learning-revolution.

Mishra, P., & Yadav, A. (2013). Of art and algorithm: rethinking technology & creativity in the 21st century. *TechTrends, 57*(3), 10–14.

MMS (2020). Mauritius Meteorological Services. http://metservice.intnet.mu.

Pultoo, A., Bullee, A. S., Meunier, J. N., Sheoraj, K., Panchoo, S., Naseeven, P., Ujoodha, M., Roocha, V., Rajcoomar, H., & Oojorah, A. (2020). Codecraft Competition: Learning to code through contests using scratch. *Journal of Science and Technology* 5(4), 40-53.

Richard, G. T. (2008). Employing Physical Computing in Education: How Teachers and Students Utilized Physical Computing to Develop Embodied and Tangible Learning Objects. *The International Journal of Technology, Knowledge and Society, 4, 4-11*.

Saranya, T., Rekha, P., Nirmala, P., Vijayalakshmi, P., Sushmitha, K. & Swetha, R. (2017). Zidong Polyhouse Using IOT. *International Journal for Research in Applied Science and Engineering Technology*, 5(2), 480-484.

Siemens, G. (2005). Connectivism: A learning theory for the digital age. International Journal of Instructional Technology and Distance Learning, 2(1).

UN-ISDR. (2008). Links between disaster risk reduction, development and climate change: A briefing for Sweden's Commission on Climate Change and Development. Commission on climate change and development, United Nations International Strategy for Disaster Reduction, Geneva, Switzerland, 5 pp.

Veletsianos, G. (2016). Emergence and innovation in digital learning, AU Press, Athabasca University.

Zaini, Z. H., Arshad, N, I., Singh, B. S. M., Nurshazlyn M. Aszemi, N. M., Subuh Anggoro, S., & Hawanti, S. (2020). A Study on Student Attitudes in Learning Programming using Physical Computing**.** *Dinamika Jurnal Ilmiah Pendidikan Dasar*, 12(1), 24-31.

Mohundranathsingh Ujoodha
Mauritius Institute of Education, Reduit, Mauritius
Email: m.ujoodha@umail.mie.ac.mu

Anand Pultoo
Lecturer, Mauritius Institute of Education, Reduit, Mauritius
Email: a.pultoo@umail.mie.ac.mu

Avinash Oojorah
Senior Lecturer and Head of Centre for Open and Distance Learning,
Mauritius Institute of Education, Reduit, Mauritius
Email: aoojorah@mie.ac.mu