National Science Experiment 2017

Sustainable Urban Living

Experiment Themes and Exemplary Topics

How to Design an Experiment: Some Guidelines for Student Teams

SENSg Device Description

Competition Judging Criteria

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Experiment Themes and Exemplary Topics

Sustainable Urban Living

Cosmopolitan cities like Singapore face a challenge of achieving sustainable growth within the constraints of space, energy and other natural resources. The government or the administration of these cities strive to provide good quality of life for all the citizens and progress with minimum impact on the natural ecology.

The academia and the industry can contribute towards resolving the challenges in achieving Sustainable Urban living. For example, some of the challenges identified by *Ministry of National Development (MND)* Singapore are stated below [1]:

- How can the quality of life and liveability be enhanced for Singaporeans in a high-density environment? Practitioners and academics need to especially focus on innovations that help to create a liveable built environment that can be planned and designed to cater to the needs of our ageing population.

- How can technologies, systems and policies create a resource-efficient district? Faced with increasing global resource constraints and environmental concerns, we need to look at the possible ways in which districts can contribute towards more sustainable outcomes such as optimizing the use of resources and reducing greenhouse gas emissions and waste.

- How can metrics and models be used to create more sustainable urban environments? Benchmarks, best practices and integrative assessment tools for cities can guide us in how metric and models can improve our analysis of cities and lead to better outcomes.

Hence the overarching theme for the National Science Experiment 2017 has been defined as *Sustainable Urban Living*. Five sub topics are proposed under this overall theme:

- Physical Comfort
- Mobility
- Neighbourhood
- Health & Wellbeing
- Arts, Culture & Heritage

These themes are not independent, and an experiment can be categorized under more than one theme. This is to be expected and is not considered a problem.

The exemplary topics listed under the themes below are not experiments because they are defined very broadly. They are exemplary *topics of investigation* that can generate many, more specific, experiments.

Physical Comfort

Physical comfort is the feeling of wellbeing brought about by internal and environmental conditions that are experienced as agreeable and associated with contentment and satisfaction. Some of the environmental parameters that can be measured using the SENSg device are temperature, humidity, noise, light, and additional specific events or user input can be recorded using the push buttons on the side of the device.

Some exemplary topics of investigation under this theme are:

- How comfortable is your classroom? (Why? How can it be improved?)

  Is your classroom comfortable? Quantify comfort factor based on thermal, visual and acoustical parameters. Ensure to collect large datasets (~ 30 Students per class) to have the ability to generate conclusive evidence to prove the hypothesis on comfort factor of classrooms.

  A simple experiment can be formulated to measure how comfortable your classroom is by correlating data from the sensor device (parameters to use are, e.g. temperature/light/sound pressure) with the number/type of button presses on the SENSg device. Small and big buttons on the device could represent if the students are feeling comfortable or uncomfortable. The number of students in the classroom (e.g. total students in classroom = 45) could be divided into 3 groups, each group would focus on a particular sensor parameter such as temperature, light, and sound. At anytime inside the classroom, respective groups would press the sensor buttons if they feel comfortable/uncomfortable depending on their comfort level of temperature (warm/normal), light intensity (too bright/dim), or sound pressure (noise level being too noisy/bearable). Specific temperature/light/sound pressure values could be retrieved from the sensor devices to correlate the number of button presses to assess the students' comfort level in class or even determine the specific time when students most feel comfortable/uncomfortable.

- Does gender have an effect on the perception of comfort in schools?

  This is similar to the experiment above, but the participant selection would need to be balanced between males and females, and there would need to be a large enough sample of both to be able to draw reasonable conclusions. Then, the responses of males and females would be compared for the parameters and perceptions described above.

- Do open public spaces make a good first impression? Are there enough places to sit (are seats conveniently located)?

Whether an open public space (parks, open spaces, natural reserves) is comfortable and presents itself well is a key to its success. Therefore, comfort measured as visual impression and the availability of places to sit plays an important role on people's capability to enjoy and experience open public spaces. We can formulate a simple experiment to measure the level of comfort in an open public space. 100 students can participate in the experiment, in groups of 10. They would be asked to visit the nearest open public space for a time span of 30 minutes. All 10 students would visit the same place at the same time. Moreover, it is convenient that the experiment can run simultaneously (e.g., July 8 at 5:00 pm). Hence, we can collect information about 10 open public spaces simultaneously, therefore targeting similar environmental and weather conditions for each space. Once students arrive the place, they need to record their first impression of the place. They press the big button one time if the first impression is "ok", two times if the first impression is "very good" or simply not press if the impression is "irrelevant". Next, the first 10 minutes they need to find a place to sit and stay there together, the next 10 minutes they can do whatever they want to do and the last 10 minutes they need to sit again together. Once the 30 minutes are over they leave the place and they need to press the button again only one time if they had problems to find available seats (in case they don't have problems to find seats, they don't need to press the button.

To answer our research question, we need to look at numerous data points generated by the SENSg device and compare the comfort properties of the 10 open public spaces studied. First, by counting the relative number of positive first impression scores (the number of times the students had pressed the button), it is possible to identify which open public spaces have a better image as a first impression. Second, by looking at the temperature, light and noise levees of the first and last 10 minutes, it is possible to infer how comfortable the place is (e.g., higher temperatures or higher light levels can be associated with no provision of shade areas). This information can be double-checked by looking at how many students pressed the button at the end of the experiment and identify which open public spaces reported problems to find available seats.

Mobility

Mobility includes private (e.g., car, motorcycle), public (e.g., MRT, bus) as well as active mobility modes (e.g., walking, cycling, skateboard, kick scooter, roller skates). You may choose to investigate various comfort parameters of these, including smoothness of ride, temperature, humidity, brightness, waiting time, perceived waiting time, etc.
Some exemplary topics of investigation under this theme could be:

- How comfortable are various public transportation modes? (parameters to be defined)

  Does the comfort factors vary between driverless and human driven trains? Comparison of comfort factor between Red, blue, yellow and green MRT lines?

- Do Singapore joggers have a favourite jogging track? (And why?)

  What makes a good jogging track? Green cover around the track or covered jogging path? Best jogging track within a park / Nature reserves?

  The experiment could have 100 joggers using the sensor devices at multiple jogging tracks. Analysis of the data generated by 100 joggers can help us infer the properties of the tracks including the trajectory, and also find out what percentage area of the path is sheltered. The light sensor can be used to detect regions below the shelter as they report lower light intensities. GPS data gathered from a smartphone can aid to plot the trajectory on a map and investigate if the type of trajectory has an impact on joggers. The Experiment can also be extended to detect the period of the jogging activity by identifying the unique pattern recorded by the IMU Sensor.

- Are paths disabled-friendly?

  To be able to find out if paths are disabled-friendly, an experiment can be conducted by calculating the difference in distance travelled by 'able-bodied' and wheelchair bound participants. In order to carry out the experiment, for example, Mode A SENSg device could be used, involving 20 'able bodied' and 20 wheelchair participants. All participants are to start at the same location and end at the same destination. This is to ensure paths taken by both 'able bodied' and wheelchair bound' participants can be compared and analyzed fairly. Device locations are required to detect the participants' travelled locations in order to be able to connect and form paths, and eventually, total distances (in metres) can be calculated. The sensor coordinates information can be retrieved from Modstore (lat long data). If results proved that wheelchair bound participants travelled significantly longer total distances than 'able bodied' participants towards the same destination, this could mean that paths they took are not disabled-friendly as they could have taken longer routes due to inconveniences they encountered towards their destination paths. If it is hard to reach participants using wheelchairs, this condition can be 'simulated' by able-bodied students.

Neighbourhood

This theme includes an exploration of your neighbourhood related to how residents use and perceive your neighbourhood. You can formulate experiments that explore ideas around having to rate the facilities/living experience in the HDB estates or nature reserves/reservoirs, or shopping zones in your neighbourhood.

Some exemplary topics of investigation under this theme could be:

- How can we foster social interaction and create a sense of community and neighbourliness in our neighbourhoods?

  A vibrant community recreation centre can have a stabilizing effect on the lives of people in our society. By providing safe and adequately equipped spaces for physical activities like dance, martial arts, yoga, basketball and other sports, community centres instil discipline, healthy exercise habits and teamwork in area youth. A top-notch recreation centre will also have dedicated rooms for social clubs and academic programs to supplement the school experience for students.

  Maintaining an active lifestyle is also a key component of a happy and healthy life as a senior citizen. Fortunately, community recreation centres don't just cater to young people. Walking clubs, fitness programs, athletic opportunities, arts and crafts classes, and various cultural activities are made available to those of retirement age by community centres and the civic organizations they partner with. Once again, there is little to no cost associated with participation in these programs, a significant benefit for those living on a fixed income.
  By providing a common destination for cultural, social, fitness and athletic events, efficiently operated recreation centres make the communities that surround them more attractive. Families are more likely to move to a neighbourhood that features a thriving community centre.

  First and foremost, let us identify a list of civic amenities in the neighbourhood. Some examples of civic amenities include community centres, public library or sports complex. In order to ensure high footfall, it is necessary to provide a conducive environment for their respective activities. The reading rooms must have minimum noise levels with good lighting and a comfortable temperature. Similarly, other activities like dance, karate or spiritual events need a comfortable environment for the user experience to be pleasant. Many publicly available documents specify the minimum requirements for above-mentioned facilities/activities.

  Let us use the SENSg device to collect various parameters like light, temperature, humidity and noise levels to analyse the environment in these civic amenities and investigate if it meets global standards. Feedback generated from the experiment can help authorities to improve facilities such that more citizens participate in all the activities resulting in a better community.

- Are our Neighbourhoods Age-friendly?

  How can communities become more age-friendly? Age-friendly development is multi-faceted and multi-disciplinary. The neighbourhood's infrastructure should ensure equal benefit to wheelchairs, bicycles, and baby strollers or be more ambitious, such as changing zoning regulations to create a more walkable downtown area where car ownership is not needed.

  Let us consider the senior citizens in our example. Older adults can be a vital asset to communities and community development, contributing their experience, leadership, and the most important factor is their positive impact on the young children in society. Many grandparents take care of their grandchildren during the day and during the evenings they must be encouraged to get out to walk, shop and socialize. One of the main concerns is the ability to walk longer distances to reach the nearest park/shopping Centre or the MRT stations. Often they feel the need to sit down for a few minutes before they proceed to their destination. Can we provide benches in the vicinity of these common places of interest to encourage them to visit places? If yes, what could be our strategy to place these benches beside the walking paths? Should it be covered or equipped with lights?

  The SENSg device can be used to further investigate our hypothesis. For the experiment, we would need the help of our senior citizens to identify the spots where they feel tired and need a bench to sit down. A student could accompany the senior citizen and press the Button provided in the device at the locations where there is a need for a bench. In addition, students can further examine the environmental parameters at the location to suggest if it needs a shelter and a solar lantern during the evenings. On a press of the button, the device would store the location and the environmental parameters as well.

  A similar experiment can also be performed to suit the needs of pregnant women in the society.

- Are covered walkways in your neighbourhood thermally comfortable?

  You can measure the thermal comfort parameters (temperature, humidity, etc.) under a number of selected covered walkways in your neighbourhood, by having 2 students simultaneously hold a SENSg device under a covered walkway (in the centre) and about 1 meter outside of the walkway. The measurement can be done for about 5-10 minutes, at various times of the day (3 or 4 times a day (e.g., at 9AM, 2PM, 7PM). The characteristics of the walkways should also be recorded, such as orientation, height-width and height-width ratio of the walkway, material of roof and floor, presence of green around it or tree shading on it, proximity to buildings on each side and shadow from buildings, etc. Students would need to select walkway sections that provide various combinations of these conditions. Then students can analyze the results and make recommendations about the placement and design of covered walkways in their neighbourhood.

Health & Wellbeing

Health and well-being as a theme covers potentially all age groups. This theme relates to physical activity (walking, doing sports, activity level of individuals and groups) in order to maintain health by avoiding a sedentary lifestyle, as well as wellbeing, which is a state of being comfortable and happy. Wellbeing can be related to reducing stress, having satisfactory social relationships, etc.

Some exemplary topics of investigation under this theme could be:

- Do students feel more content:

  Indoors or outdoors?

  Feeling contented in indoors or outdoors can be inferred on the basis of time spent at a location. SENSg data can be used to recognize if students are in an air-conditioned space or outside. An experiment can be formulated where 200 (the larger the number of participants, the better) students use the device for a week, including the weekend, and the experiment would focus on their 'free' time, meaning the time they spend outside of school and home (resting, sleeping), Temperature and humidity data collected from the sensor device can be used as one of the parameters to determine whether students prefer to spend most of the time in an indoor or outdoor environment. ..If there is drop in temperature and humidity one can conclude that a student is at an indoor location, otherwise outdoors. Students can be instructed to record where they are on a date and time, what activity they are performing (eating, reading, socializing, online socializing, studying, etc.), if they are alone or in a social group, and they can press the button on the sensor to tell us if they are 'happy'. This data can then be analysed to see the effect of activity, location (indoors, outdoors, type of place), alone or in group, noise level, and activity on the happiness of students.

  When being active or passive?

  Sensor's accelerometer can be used as one of the parameters to capture readings associated with students' activity level. Higher accelerometer readings can be associated with students' higher physical activity levels.

  A button press of students can tell us if they are enjoying their physical activity or not. They can press the big butting when they enjoy their activity, and the small button when they don't.

How to Design an Experiment:

Some Guidelines for Student Teams

Introduction

National Science Experiment 2017 is designed such that the student teams from various schools propose their own experiment, using the SENSg device to collect relevant data, analysing the data, and deriving conclusions. In this process, student teams will:

- Define a research question
- Formulate a hypothesis
- Collect data
- Analyse data
- Derive findings and conclusions
- Make implementation and policy recommendations

Defining a research question

An effective research can be conducted when the statement of objectives is clear. It is also important that the research problem that guides your experiment is not too broad; otherwise, it will be difficult to adequately address the problem in the space and time allowed.
Let us find out how one would narrow the topic to something manageable yet interesting and impactful.

A topic is too broad to be manageable when you find that you have too many different, and oftentimes conflicting or only remotely related ideas about how to investigate the research problem. **Here are some strategies to help narrow your topic:**

- Choose one facet of the research problem to analyse
- Explore unit analysis of your problem such that smaller broken down units can be analysed more precisely
- Design a study around specific relationships between the various variables in your study can help you constrict the scope of analysis
- Determining which variables affect the solution to the problem
- Determining the degree to which each variable can be controlled
- Determining the functional relationships between the variables and which variables are critical to the solution of the problem
- Focus your topic in terms of a specific type of class of people, place or phenomena

However, your starting point should not be so narrowly defined that you unnecessarily constrict your opportunity to investigate the topic thoroughly. A research problem that is too narrowly defined leads to any of the following problems:

- You don't find enough information and what you do find is tangential or irrelevant
- You find information that is so specific that it can't lead to any significant conclusions
- The research problem so specific that it limits opportunities to generalize or apply the results to other contexts
- The significance of the research problem is limited to only a very small, unique population

You can also apply the six-question strategy to broaden your topic. (Who, What, Where, How and Why)

Reflecting upon these six questions during your initial review of the literature can help you formulate ways to expand the parameters of your initial research problem, providing an opportunity to identify new avenues of investigation and centring your study around gaps in the literature when answers to questions cannot be found. Once you've identified additional directions in which to proceed with your topic, you can try narrowing it down again, if needed.

Formulating a Hypothesis

Read existing research. Gather all the information you can about the topic you've selected and be certain that your information sources are unbiased, accurate, and comprehensive.

You can find information in textbooks, at a library, and online (journals, databases, Google scholar, other resources), or seek help from teachers, librarians, and your peers.
Example: Study how environmental parameters impact human emotions
Read studies testing the effects of ambient temperature or humidity on human emotions.

Analyse the literature. Spend some time reading the materials you've collected. As you do so, look for and make note of unanswered questions in the literature. These can provide excellent ideas for areas to investigate.

- For example, if you are interested in the effects of environment on the human body, but notice that nobody seems to have explored whether weather affects males differently than it does females, this could be something to formulate a hypothesis about.
- Examining these types of questions provides an excellent way for you to set yourself apart by filling in important missing links or evidence in the study conducted so far.

Determine your variables. A ***generalizing hypothesis*** describes a pattern you think may exist between two variables: an independent variable and a dependent variable. If your experiments confirm the pattern, you may decide to suggest a reason that the pattern exists or a mechanism that generates the pattern. The reason or mechanism you suggest is an ***explanatory hypothesis***.

- You can think of the independent variable as the one that is causing difference or effect to occur. In the examples, the independent variable would be biological sex, i.e. whether a person is male or female.
- The dependent variable is what is affected by (i.e. "depends" on) the independent variable. In the examples above, the dependent variable would be the measured impact of the environment.
- Your hypothesis should only suggest one relationship. Most importantly, it should only have one independent variable. If you have more than one, you won't be able to determine which one is the source of any effects you might observe.

Generate a simple hypothesis. Once you've spent some time thinking about your research question and variables, write down your initial idea about how the variables might be related to a simple declarative statement.

- Don't worry too much at this point about being precise or detailed.
- In the examples above, one hypothesis would make a statement about whether a person's biological sex might impact the way the person is affected by the environment; for example, at this point, your hypothesis might simply be: "a person's gender is related to how the environment affects his/her mood."

Decide on direction. Hypotheses can either be directional or non-directional. A non-directional hypothesis simply says that one variable affects the other in some way, but does not say specifically in what way. A directional hypothesis provides more information about the nature (or "direction") of the relationship, stating specifically how one variable affects the other.

Using our example, our non-directional hypotheses would be "there is a relationship between a person's gender and how much the environmental conditions affect his/her mood".

Directional predictions using the same example hypotheses above would be: "Females will experience a greater swing in the mood after having a stressful walk under the hot sun than males." Indeed, these predictions and the hypotheses that allow for them are very different kinds of statements. More on this distinction below.

Get specific. Once you have an initial idea on paper, it's time to start refining. Make your **hypotheses** as specific as you can, so it's clear exactly what ideas you will be testing and make your **predictions** specific and measurable so that they provide evidence of a relationship between the variables.

Where necessary, specify the population (i.e. the people or things) about which you hope to uncover new knowledge. For example, if you were only interested the effects of environmental factors on elderly people, your prediction might read: "Females over the age of 65 will experience greater mood swings than the males of the same age."

Make sure it is testable. Your hypothesis must suggest a relationship between two variables or a reason that two variables are related that can feasibly be observed and measured in the **real and observable world**.

For example, you would not want to make the hypothesis: "red is the prettiest colour." This statement is an opinion and it cannot be tested with an experiment. However, proposing the generalizing hypothesis that red is the most popular colour is testable with a simple random survey. If you do indeed confirm that red is the most popular colour, your next step may be to ask: Why is red the most popular colour?

Test your hypothesis. Make your observations or conduct your experiment. Your evidence may allow you to reject your null hypotheses, thus lending support to your experimental hypothesis. However, your evidence may not allow you to reject your null hypothesis and this is okay. Any result is important, even when your result sends you back to the drawing board. Constantly having to go "back to the drawing board" and refine your ideas is how authentic science really works!

Data Collection

Data collection is the process of gathering and measuring information on variables of interest, in a structured manner that enables one to answer stated research questions, test hypotheses, and evaluate outcomes.

The results of research and its methods are directly dependent on the collected data and its analysis. It is extremely important to maintain integrity (accuracy and completeness) while collecting data. Accurately collecting data ensures that research questions are answered correctly, research/experiments are repeatable and validated, and other researchers are not misled about results and can benefit from your research findings.

The scale (number of devices to be used) of the experiment depends on the chosen problem statement and hypothesis. For example, an experiment can be structured in a way that many devices are distributed amongst the school students and are requested to help in collecting data to fulfil the objectives of the experiment. In order for an experiment result to be impactful, the collected data volume should be sufficiently substantial.

SENSg Device Description

“SENSg” (pronounced “SENSE-SG”) device measures and stores data on motion, temperature, humidity, atmospheric pressure, light intensity and sound pressure levels. The device uses Wi-Fi signals to localize itself, and periodically uploads sensor data to a secured database if it is in a range of a known access point (School premises). The sensor data is anonymous and stored securely in the cloud.

Figure 1: SENSg Device

How SENSg Localizes

The SENSg nodes use a pre-recorded ‘radio map’ of Singapore which determines location by triangulating between different Wi-Fi access points as shown in the Figure below. The accuracy of this localization technique depends heavily on how many Wi-Fi hotspots the sensors measure. In large open spaces, the localization accuracy can be diminished, whereas, in heavily built-up areas, it can improve.

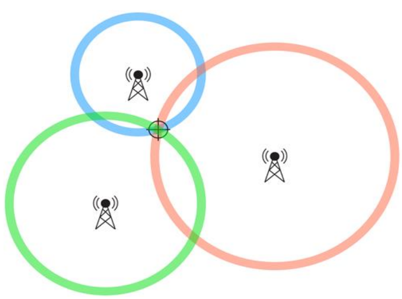
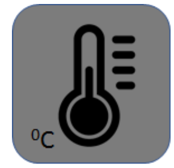


Figure 2: Wi-Fi based location services

Relative Humidity & Ambient Temperature



A humidity sensor (or hygrometer) senses, measures and reports the relative humidity in the air. It, therefore, measures both moisture and air temperature. Relative humidity is the ratio of actual moisture in the air to the highest amount of moisture that can be held at that air temperature. The warmer the air temperature is, the more moisture it can hold. As such, we have designed the SENSg devices with multiple perforations to increase ventilation and mounted the sensor in a way to minimize heat transfer from other electronic sensors.

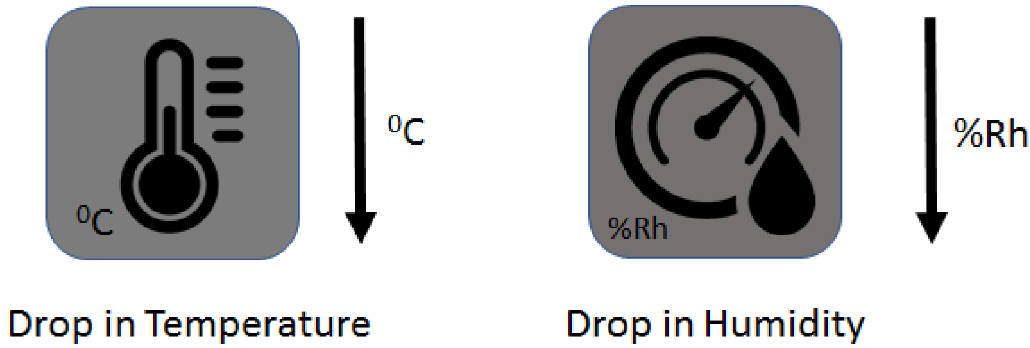
Humidity sensors can be used as a monitoring and preventive measure in homes for people with illnesses that are affected by humidity. They are also found as part of home heating, ventilating, and air conditioning systems (HVAC systems).Air conditioners cool homes by removing heat and moisture from the air, hence the humidity levels are quite low. They can also be found in offices, cars, museums, industrial spaces and greenhouses and can be used in meteorology stations to report and predict the weather.

A temperature sensor positioned so as to read the local temperature around the device is referred as or ambient temperature sensor. That means it has to be isolated from any heat producing parts of the machine and preferably have relatively good air circulation as machine heat would eventually heat up a closed unit

Detect user's presence in an air-conditioned environment

Air-conditioning equipment usually reduces the absolute humidity of the air processed by the system. Since humans perspire to provide natural cooling by the evaporation of perspiration from the skin, drier air (up to a point) improves the comfort provided. The comfort air conditioner is designed to create a 40% to 60% relative humidity in the occupied space.

Thereby considering the change in the temperature and the humidity as explained above, one can conclude on the time duration spent by the user in an air conditioned environment. The obtained data can be extended to determine the impact on the environment by the use of Air conditioners.



Changes in physical parameters when in an air-conditioned environment

Note: The one major factor that will affect the accuracy of the device is temperature. The graph on page three of the sensor datasheet shows that the sensor works best in between the temperatures of -40 to 85 degrees Celsius (-40 to 185 degrees Fahrenheit).

Pressure

Barometric pressure sensors measure the absolute pressure of the air around them. This pressure varies with both the weather and altitude. Depending on how you interpret the data, you can monitor changes in the weather, measure altitude, or any other tasks that require an accurate pressure reading.

The SENSg device's pressure sensor consists of a piezo-resistive sensor. Change in pressure results in a change in electrical resistivity of the sensor, and altering current or voltage readout which is correlated to pressure readings. The measured pressure allows for estimation of the altitude, i.e. the height above sea level you are at.

What is Atmospheric Pressure?

The definition of pressure is a force "pressing" on an area. A common unit of pressure is pounds per square inch (psi). One pound, pressing on one square inch, equals one psi. The SI unit is newtons per square meter, which are called pascals (Pa).

There are lots of situations in which pressure can be measured (gravity, pull, etc.), but right now we're interested in atmospheric pressure, which is the force that the air around you is exerting on everything. The weight of the gasses in the atmosphere creates atmospheric pressure. One doesn't normally notice that air weighs anything, but if you took a one inch wide column of air from sea level to the top of the atmosphere, it would weigh about 14.7 pounds. (A 1 cm wide column of air would weigh about 1 kg.) This weight, pressing down on the footprint of that column, creates the atmospheric pressure that we can measure and quantify.

Because that inch-wide column of air weighs about 14.7 pounds and is pressing on one square inch, it follows that the average sea level pressure is about 14.7 pounds per square inch (psi), or 101325 Pascals. This will drop about 4% for each 1000 feet (or 300 meters) you ascend. The higher you get, the less pressure you'll see, because the column to the top of the atmosphere is that much shorter and therefore weighs less. This is useful to know because by measuring the pressure and doing some math, you can determine your altitude.

Fun fact: The air pressure at 12,500 feet (3810 meters) is only half of that at sea level. In other words, half of the mass of the atmosphere is below 12,500 feet, and the air at 12,500 feet is half as dense as that at sea level. No wonder you have a harder time breathing up there.

The Sensor outputs absolute pressure in Pascals (Pa). One pascal is a very small amount of pressure, approximately the amount that a sheet of paper will exert resting on a table. You will more often see measurements in hectopascals (1 hPa = 100 Pa) or kilopascals (1 kPa = 1000 Pa). The Arduino library we've provided outputs floating-point values in hPa, which also happens to equal one millibar (mbar).

Here are some conversions to other pressure units:

1 hPa = 100 Pa = 1 mbar = 0.001 bar

1 hPa = 0.75006168 Torr

1 hPa = 0.01450377 psi (pounds per square inch)

1 hPa = 0.02953337 inHg (inches of mercury)

1 hpa = 0.00098692 atm (standard atmospheres)

Temperature Effects

Since the temperature affects the density of a gas, and density affects the mass of a gas, and mass affects the pressure (whew), atmospheric pressure will change dramatically with temperature. Pilots know this as "density altitude", which makes it easier to take off on a cold day than a hot one because the air is denser and has a greater aerodynamic effect.

To compensate for temperature, the sensor includes a rather good temperature sensor as well as a pressure sensor. To perform a pressure reading, you first take a temperature reading, then combine that with a raw pressure reading to come up with a final temperature-compensated pressure measurement. (Don't worry, the SENSg device firmware makes all of this very easy)

Measuring Absolute Pressure:
As we just mentioned, if your application requires measuring absolute pressure, all you have to

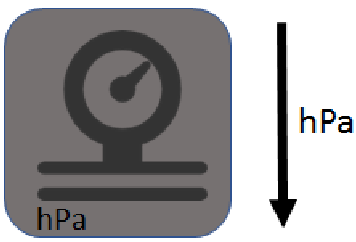
do is get a temperature reading, then perform a pressure reading (see the example sketch for details). The final pressure reading will be in hPa = mbar. If you wish, you can convert this to a different unit using the above conversion factors.

Note that the absolute pressure of the atmosphere will vary with both your altitude and the current weather patterns, both of which are useful things to measure.

Determining Altitude

Since pressure varies with altitude, you can use a pressure sensor to measure altitude (with a few caveats).

The average pressure of the atmosphere at sea level is 1013.25 hPa (or mbar). This drops off to zero as you climb towards the vacuum of space. Because the curve of this drop-off is well understood, you can compute the altitude difference between two pressure measurements (p and p0) by using this equation:



$$\text{altitude} = 44330 * \left(1 - \left(\frac{p}{p_0}\right)^{\frac{1}{5.255}}\right)$$

Altitude calculations based atmospheric pressure

There are two ways you can take advantage of this.

If you use sea level pressure (1013.25 hPa) as the baseline pressure (p0), the output of the equation will be your current altitude above sea level.

Or, if you take a single pressure reading at your current location, and use that as your baseline (p0), all subsequent pressure readings will result in relative altitude changes from the baseline. Climb the stairs and you should see the altitude go from zero to 3 or 4 meters. Go down to the basement, and you'll see -3 or -4 meters.

Accuracy: How accurate is this? The theoretical noise level at the sensor's highest resolution is 0.25m (about 10 inches), though in practice we see noise on the order of 1m (40 inches). You can improve the accuracy by taking a large set of readings and averaging them, although this will slow down your sample rate and response time.

Weather: You should also remember that pressure changes due to weather will affect your altitude readings. The best accuracy will be obtained if you take a “fresh” p0 when you need it and don’t rely on it to be accurate for extended periods due to changes in the weather.

Maximum altitude: The sensors can’t measure all the way down to vacuum (or up to space). It’s advertised lower limit is about 300 hPa (or mbar), which corresponds to an altitude of about 3000m or 30,000 feet. People have flown these to higher altitudes and gotten useful results, but this isn’t guaranteed or likely to be accurate. (You might consider using GPS for high-altitude measurements).

Minimum altitude: Similarly, this sensor isn’t suited for large pressures either. The advertised upper limit is 1100 hPa=mbar (or 16 psi), which is about 500 feet below sea level (that’s in the air - the sensor isn’t submersible in water). This sensor isn’t a good choice for submersible or compressed-gas measurements.

Temperature

The SENSg device contains an infrared (IR) thermometer that provides non-contact temperature sensing. It measures the temperature of an object by sensing the infrared radiation emitted by the object and converting the voltage generated to a digital reading of the temperature. The lens covering the IR thermometer sensor requires uses special materials to minimize reflection and absorption by the lens material.

The sensor can accurately detect signals in almost 90° field of view of the sensor. The final calculated target object temperature is an integration of all of the signals present in the sensor field of view. Therefore, the ability of the sensor to accurately calculate the temperature of a target depends on the ability of the IR sensor to capture the majority of its signal from the target. This capture effectiveness, in turn, depends on two factors: the angle of incidence and the distance of the sensor from the target.

The figure below illustrates the dependence of the TMP006 on the angle of incidence compared to the IR signal absorption. For this test, the intensity of an input signal was held constant and was moved throughout the sensor field of view. This figure shows that the majority of the received signal comes from IR sources located at 0° angles of incidence.

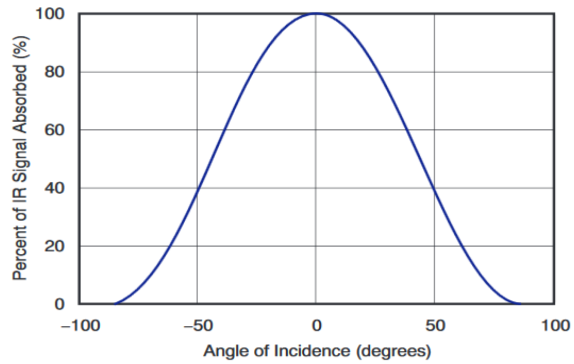


Figure 3: Percentage of IR Signal Absorbed by Sensor versus Angle of Incidence

As a design guideline, place the device directly underneath the target object with the surface of the target parallel to the device, so the angle of incidence between them is 0°.

The distance that the device should be placed from the target is largely dictated by the size of the target. Smaller targets must be placed closer to the device to ensure that the majority of the IR signal captured by the sensor is emitted from the target. A circular target should be placed at a distance less than one-half of the radius of the target to ensure at least 90% of the IR signal that the sensor captures is from the target.

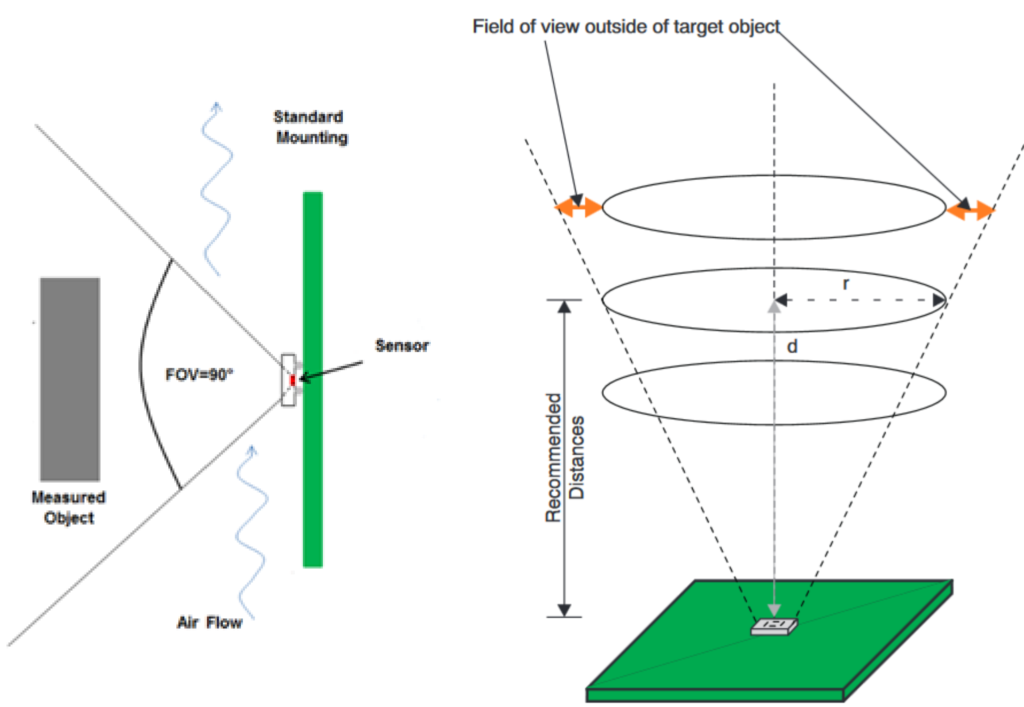


Figure 4: Relationship between target object size and distance from the device

Sound

The microphone in the SENSg device converts acoustic (sound) pressure waves to electrical signals and provides the Sound Pressure Level readings in decibels. Typical ambient noise in Singapore measured at night is around 55 decibels (dB), reaching up to around 80 dB in the day. The SENSg devices use special capacitive micro electromechanical systems (MEMS) microphones to measure sound pressure level for measuring city noise.

What is loud? Noise is a sound that disturbs or harms.

What we condemn as noise depends not only on the noise level. There are social, physical and psychological factors. Besides the type of noise and personal noise sensitivity, there are the expectations of a person which is crucial to its assessment of noise. The "desired" noise is not the classification in 'noisy' or 'too loud'. Kurt Tucholsky wrote: "Our own dog does not make noise, it only barks" and "noise is the sound of the others."

Sound sources (noise) Examples with distance	**Sound pressure Level L_p dB SPL**
Jet aircraft, 50 m away	140
Threshold of pain	130
Threshold of discomfort	120
Chainsaw, 1 m distance	110
Disco, 1 m from speaker	100
Diesel truck, 10 m away	90
Kerbside of busy road, 5 m	80
Vacuum cleaner, distance 1 m	70
Conversational speech, 1 m	60
Average home	50
Quiet library	40
Quiet bedroom at night	30
Background in TV studio	20
Rustling leaves in the distance	10
Hearing threshold	0

Table -1 – Sound pressure sensors

Light

Light sensors have all sorts of practical uses in the modern era, most notably in devices with auto-brightness for their screens and in digital cameras to adjust exposure. The SENSg devices contain a light sensor to measure light. Light Sensor will detect the brightness of its surroundings. While there are many properties of light that can help us categorize its brightness, the sensor measures illuminance (measured in lux (lx)). Photodiodes are often used in applications such as street lighting control, backlight calibration, etc. where light must be adjusted according to how humans perceive light.

How Light Detection Works

Now that our sensor is working, let's take a more in-depth look at what is going on inside the senor. As mentioned earlier, the sensor measures illuminance. If you're unfamiliar with illuminance, it is a measure of the total quantity of visible light emitted by a source (referred to as luminous flux, measured in lumens (lm)) divided by an area in square meters. More notationally, 1 lx = 1 lm/m². Along with these, there are other properties of light that are unfortunately all named using the same Latin root for light, so it can be hard to keep them straight. Here's a diagram to hopefully *elucidate* the differences:

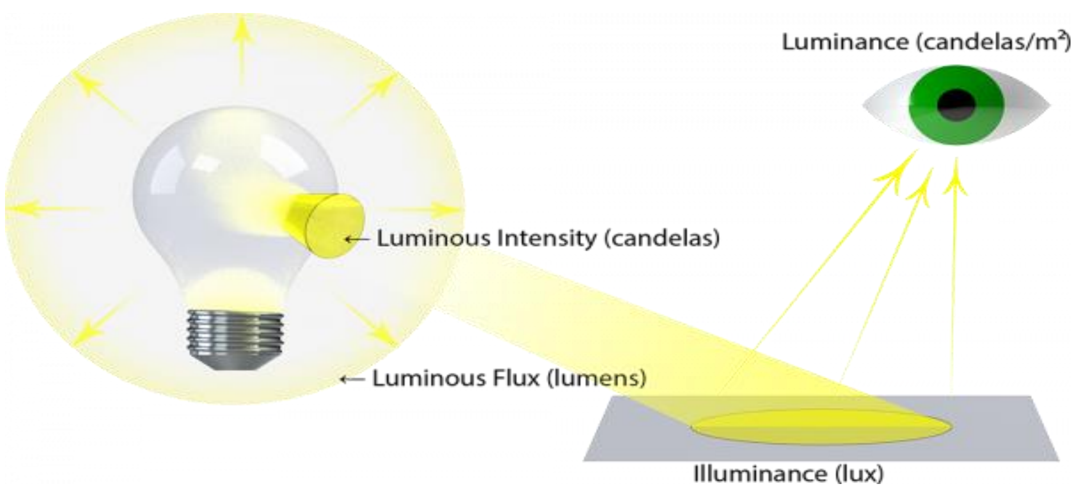


Figure 5: Diagram depicting the nuances between the various measurements of light.

Why does the sensor measure illuminance? In most practices, measuring the intensity of light without factoring in distance is very difficult, and puzzled early astronomers for a long time. In short, there is apparent magnitude (how bright a source appears) and absolute magnitude (how bright the source actually is). Two sources of different absolute magnitudes can have the same apparent magnitude depending on their distance from the observer.

For example, if you have a bright source far away and a dim source very close, they can appear to have the same brightness because the brighter source's light will have to dissipate over a larger volume. This is why the sensor will read a smaller value if you move the same source of light farther away from it, essentially increasing the amount of space that the same amount of light has to fill between the source and the sensor (i.e. reducing the illuminance, as you're dividing by a larger surface area of the light-sphere generated by the source).

Here's a table of the typical illuminance from common sources of visible light:

Examples	
Illuminance	**Surfaces illuminated by:**
0.0001 lux	Moonless, overcast night sky (starlight)[3]
0.002 lux	Moonless clear night sky with airglow[3]
0.27–1.0 lux	Full moon on a clear night[3][4]
3.4 lux	Dark limit of civil twilight under a clear sky[5]
50 lux	Family living room lights (Australia, 1998)[6]
80 lux	Office building hallway/toilet lighting[7][8]
100 lux	Very dark overcast day[3]
320–500 lux	Office lighting[6][9][10][11]
400 lux	Sunrise or sunset on a clear day.
1000 lux	Overcast day;[3] typical TV studio lighting
10 000–25 000 lux	Full daylight (not direct sun)[3]
32 000–100 000 lux	Direct sunlight

Table -2

Inertial Measurement Unit

The SENSg device contains a MEMS Inertial Measurement Unit (IMU) which combines a 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer in the same chip. This chip also comes with a built-in pedometer function to fuse sensor data and provide the step count reading.

Accelerometers are devices that measure acceleration, which is the rate of change of the velocity of an object. They measure in meters per second squared (m/s^2) or in G-forces (g). A single G-force for us here on planet Earth is equivalent to 9.8 m/s^2, but this does vary slightly with elevation (and will be a different value on different planets due to variations in gravitational pull).

Accelerometers are electromechanical devices that sense either static or dynamic forces of acceleration. Static forces include gravity, while dynamic forces can include vibrations and movement.

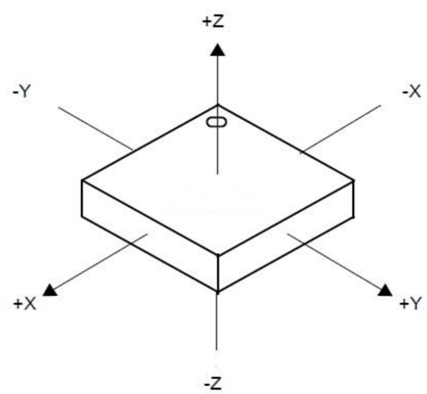
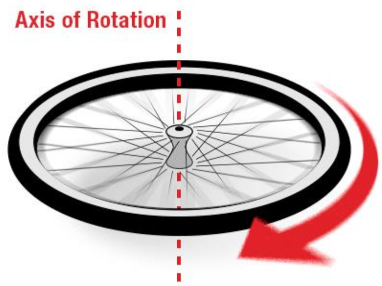


Figure 6: Axes of measurement for a triple axis accelerometer

Some most common applications of the accelerometer can be found here.

Gyroscopes, or gyros, are devices that measure or maintain rotational motion. MEMS (microelectromechanical system) gyros are small, inexpensive sensors that measure angular velocity. The units of angular velocity are measured in degrees per second (°/s) or revolutions per second (RPS). Angular velocity is simply a measurement of the speed of rotation.



The z axis of the gyro below aligns with the axis of rotation of the wheel.

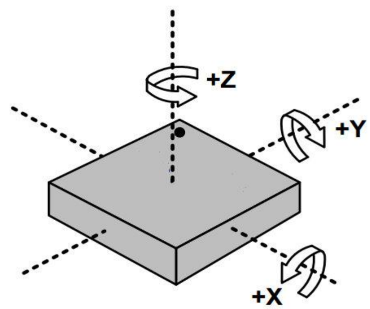


Figure 7: Measuring angular velocity using gyroscope `

If you attach the sensor to the wheel shown above, you can measure the angular velocity of the z axis of the gyro. The other two axes would not measure any rotation.
Imagine if the wheel spins once per second. It would have an angular velocity of 360 degrees per second. The spinning direction of the wheel is also important. Is it clockwise around the axis, or is it counter-clockwise?

A triple axis MEMS gyroscope, similar to the one pictured above, can measure rotation around three axes: x, y, and z. Some gyros come in single and dual axis varieties, but the triple axis gyro in a single chip is becoming smaller, less expensive, and more popular.
Gyros are often used on objects that are not spinning very fast at all. Aircrafts (hopefully) do not spin. Instead, they rotate a few degrees on each axis. By detecting these small changes gyros help stabilize the flight of the aircraft. Also, note that the acceleration or linear velocity of the aircraft does not affect the measurement of the gyro. Gyros only measure angular velocity.

All of us probably are aware of the fact that the magnets create magnetic fields; the earth has a magnetic field; current flowing in a wire also generate a magnetic field. But have we ever realized that the fields are generated also by our heart and brain? However, what differs between the magnetic field generated by a magnet and that generated by brain and heart is the magnitude of magnetic field. The following figure shows the magnitude of magnetic fields generated by various sources.

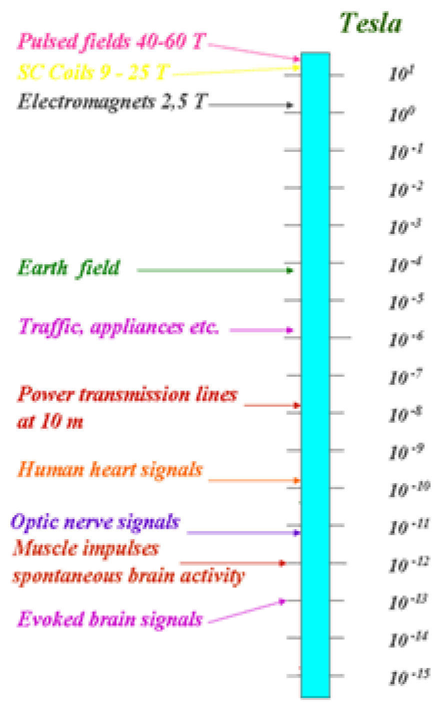


Figure 8: Magnitude of magnetic fields

We all are surrounded by magnetic fields. Magnetic fields are generated by flowing electrical current in various electrical/electronic appliances; TV, computers, power transmission lines, etc. Earth also has its own magnetic field, though relatively small. Earth magnetic field is largest at the poles (~ 60 000 nT) and smallest as the equator (~ 30 000 nT).Measurement of the magnetic fields is of interest for various scientific purposes, navigation, etc. Measurement of these fields is done by sensing devices called magnetometers.

Magnetometers are devices that measure magnetic fields. A magnetometer is an instrument with a sensor that measures magnetic flux density B (in units of Tesla or As/ m2). Magnetometers refer to sensors used for sensing magnetic fields OR to systems which measure magnetic field using one or more sensors.
Since magnetic flux density in the air is directly proportional to magnetic field strength, a magnetometer is capable of detecting fluctuations in the Earth's field.

Materials that distort magnetic flux lines are known as magnetic and include materials such as magnetite that possess magnetic fields of their own, as well as very high magnetic conductivity. Such materials create distortions in the Earth's magnetic flux that is flowing around them. Magnetometers detect these distortions.
A magnetometer measures magnetic flux density at the point in space where the sensor is located. Magnetic field drops in intensity with the cube of the distance from the object. Therefore, the maximum distance that a given magnetometer can detect the object is directly proportional to the cube root of the magnetometer's sensitivity. The sensitivity is commonly measured in Tesla.

In this section we have shared in detail about the sensors available on the SENSg device and we conclude with a table of the raw data captured on the data analytics platform – MODSTORE.

#	id	date	time	humidity	light	mode	noise	pressure	steps	temp	irtemp	meanmag	meangyr	stdgyr
1	507202	2016-07-11	00:40:43	65.0	0	1	25	100925	96040	30.07	23.98	795	5	1
2	507202	2016-07-11	02:05:04	65.0	0	1	25	100824	96040	30.12	24.2	793	5	1
3	507202	2016-07-11	03:29:25	65.5	0	1	25	100779	96040	30.14	23.81	794	5	0
4	507202	2016-07-11	04:53:43	65.5	0	1	25	100801	96040	30.12	23.54	795	5	1
5	507202	2016-07-11	06:18:02	65.5	0	1	53	100825	96040	30.02	23.54	793	5	1
6	507202	2016-07-11	07:42:22	65.0	0	1	52	100931	96040	28.49	20.76	792	5	1
7	507202	2016-07-11	08:30:28	65.0	0	1	65	101018	96040	27.89	19.75	748	316	305
8	507202	2016-07-11	08:30:48	65.0	0	6	62	100992	96040	27.9	20.03	191	589	770
9	507202	2016-07-11	08:31:09	65.0	0	4	55	100992	96040	27.94	20.37	503	5	1
10	507202	2016-07-11	08:31:29	65.0	0	4	56	100997	96040	27.95	20.42	505	6	1

Table 3: Raw data from sensors

Examples

Some illustrations of how various the raw data from sensors were used to produce the processed data variables are given below:

- **Stairs / Steps calculation**

The Number of steps and stairs taken by the students can be estimated using the SENSg device. The algorithm to estimate steps and stairs considers sensors like IMU and pressure sensor. The IMU sensor would help in sensing the movement and the direction in 3D space. The pressure sensor helps us in differentiating between the horizontal movement and vertical rise when one takes the stairs.

- **Transport System Analysis**

The transportation mode such as walking, bus, train (MRT, LRT) or car denotes an important characteristic of the user's context. Some studies show that personal mobility accounts for about two thirds of the total transportation energy use in a city. Even more interesting, transport has several negative effects that are reflected both, in the environmental and human health. For instances, combining the SENSg sensor's information with sophisticated algorithms, it is possible to estimate CO2 emissions produced (what would be the reduction of CO2 emissions if a certain number of car trips could be replaced by MRT/Bus?). Similarly, the large data generated by the NSE, can be used to investigate what's the impact of the MRT/bus stop distributions on the mobility parents (having an MRT/bus stop within walking distance from home -no further away than 10 min- would reduce the need to own a car?).

- **Points of interest (PoI)**

The points of interest (PoI) shows a brief understanding about the motivation behind people's movements. For example, what are the factors that drive people to move across a city in-between locations (studying, shopping, eating, etc.)? People movements are highly related to the distribution of the activities (school, mall, food court). A better understanding of the PoI is highly useful due to it has a direct impact on the transportation modes and travel routes. Information about people mobility and activity context can be extracted from a proper processing information from the NSE data. Moreover, by introducing modern visualization techniques, we can interactively explore which places in Singapore are the most popular ones.

- **Activity Analysis**

Using the Inertial measurement sensors one can measure the activity levels of an individual (Steps count/ Stairs count / Sleep durations). In order to detect if the user is asleep, we use the data generated from a combination of sensors like IMU, Light sensor and Noise sensors. Some of the questions that arise which are particularly interesting for students: Are Singaporean students getting the required minimum number of hours of sleep? And At which time of day are they are being most active?

Below is the summary of the above mentioned processed data variables:

#	id	date	aircon_co2	aircon_energy	am_travel_distance	am_travel_mode	am_travel_duration	pm_travel_distance	pm_travel_mode
1	708784	2016-07-11	3028.5	7.0105	0.0		0.0	20.7559	Train + Bus
2	708784	2016-07-12	5902.5	13.663	18.4845	Bus + Car	3253.0	20.3949	Train + Bus
3	708784	2016-07-13	6428.1	14.88	19.894	Train + Bus	3962.0	16.6876	
4	708784	2016-07-14	6531.1	15.118	20.2486	Train + Bus	4288.0	19.1408	Train + Bus
5	708584	2016-07-11	1741.5	4.0314	0.0		0.0	2.7954	
6	708584	2016-07-12	2279.3	5.2761	2.7566	Bus	608.0	0.0	

Table 4: Screenshot of the processed data on MODSTORE

The above mentioned data variables are available to use on the MODSTORE platform. However the Student group has to consider the context of the experiment before taking into the consideration of these variables into their analysis.

Device modes

The SENSg devices are available in two versions. The versions are differentiated by few changes in the software and below are the details:

Mode – A

Devices in this mode record sensor data once in 15 sec. The stored information is then uploaded to the designated server using the Wi-Fi infrastructure setup in the respective schools.
Note: The device goes to low power mode when it remains stationary for more than ‘2’ sec. In low power mode, the device records data once in 30min.

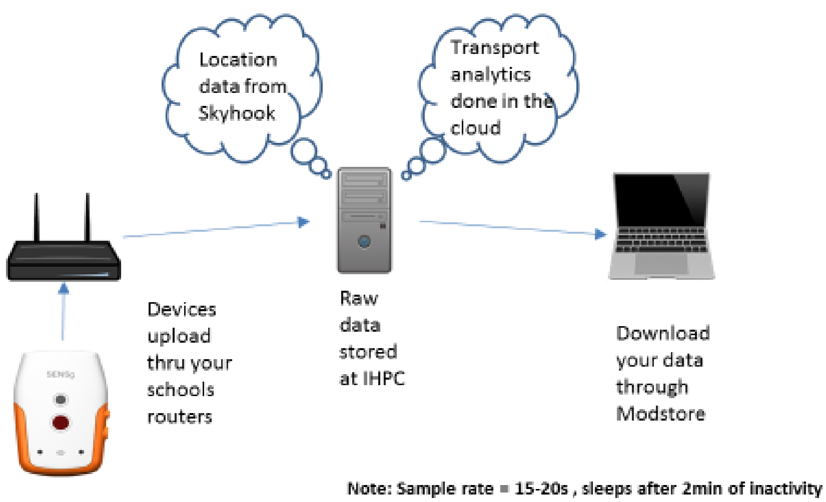


Figure 9: Data Flow diagram in Mode A

Mode – B

Devices configured in mode B can be used to record data at a very high sampling rate (<1 sec). The devices are to be connected to your phone (using Wi-Fi hotspot method) to collect and store data. Detailed instructions shall be provided.

Note: The device does not go into sleep mode and the data stored in your mobile can be downloaded in CSV format. The data analytics tool shall allow you to upload CSV data manually.

- Battery consumption in this mode would be quite high and may require frequent charging. Suggest using a battery bank during the experiments.
- Recommend using this mode in experiments requiring high sampling rate. Some examples are given below:
- Motion analysis of vehicles, elevators or any other objects.
- All experiments requiring sensor data to be sampled at less than 13secs interval.

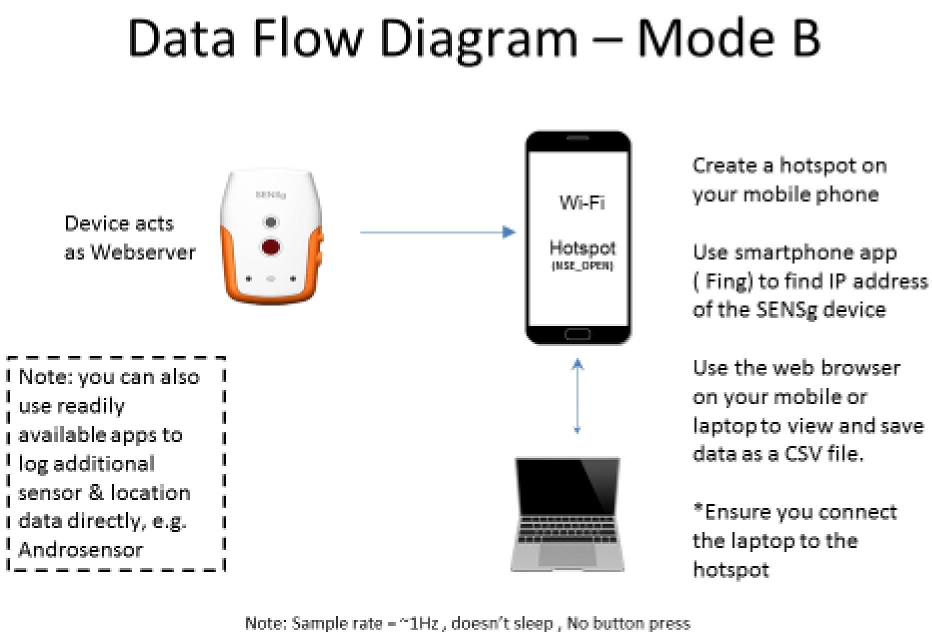


Figure 10: Data flow diagram in Mode B

Input Interfaces

Figure 11: Input push buttons

The device is equipped with two buttons on its sides. The input buttons are distinguished by their shape and size, as one of them is in a circle shape with the latter being oval and bigger as well. These buttons can be used to record the occurrence of significant events in your study. The buttons can be associated with specific questions or statements that you incorporate in your experiment. For example, a participant can press a button to give a "yes" or "no" answer to your question. Participants can later use the NSE web portal to provide additional information about the button pushes they perform each day.

Comparison of the two variants of SENSg Device

Features	*Mode A*	*Mode B*
Push Button inputs	*Yes*	*No*
Localization	*Yes*	*No - Use hand phone*
Automatic upload of data	*Yes*	*No*
Low power mode	*Yes – Sleeps after 2 min of inactivity*	*No*
Sampling rate	*13 sec*	*0.25 sec*

Table 5: Feature comparison of Mode A and Mode B

Competition Judging Criteria

Your competition entry will be judged on four categories. A detailed description of what is expected from your report and supporting material can be found below.

No.	Criteria	Percentage
1	Research • Problem identification – Definition of the problem and hypothesis • Sources of information – Types and number of quality sources cited to strengthen the claim • Problem Analysis – Depth to which the problem was analysed by the team	25%
2	Solution • Innovation – Whether the findings provide value-added novelty • Impact – Whether the findings have the potential to impact and improve public policy in Singapore • Technical Accuracy – Solution exhibits accurate analytics and technical depth	25%
3	Experiment • Experiment Plan – Clear, well-structured plan • Execution – Methodology • Error Analysis – Limitations and possible sources of errors identified and quantified	25%
4	Reporting / Supporting Materials • Quality of Text – Level of detail and depth of description • Quality of Visualisations – Visualisation schemes used to represent context, analysis and findings • Presentation Effectiveness – Message delivery and organisation of the report	25%
	Total	**100%**

References

1. Sustainable Urban living – M & D, Singapore
2. Improving Your Lab Report
3. Detailed reports on noise measurements in various environments: Link1, Link2.
4. How Can We Build A Vibrant Future City?
5. What Makes a Successful Place? - Project for Public Spaces
6. Village and Community Halls
7. Strengthening people and places: the role and value of community and neighbourhood centres
8. Economic and Social Impact Study: Community and Neighbourhood Centres Sector
9. Sports facilities advisory
10. Community-Based Urban Development: Evolving Urban Paradigms in Singapore and Seoul
11. The meaning of comfort in residential environments
12. Comforting Classroom
13. Teaching Children about Aspects of Comfort in the Built Environment
14. Occupants' Comfort in School Buildings
15. Provide comfortable environments
16. Design considerations for a youth centres
17. Environmental Comfort in School Buildings
18. Is Your School or Classroom a Comfortable Place to Learn?
19. The Impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis
20. Basics of Error Analysis
21. An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements 2nd Edition

Appendix

Sample Experiments

Few examples from past year's experiments and competitions:

1. Are students in Singapore leading a healthy lifestyle?

According to Straits' Times, a study shows that Singapore Teens are not active enough which could lead to health problems when they become adults. The teams envisioned to investigate if the students live a healthy lifestyle. Some of the factors considered in the study include the activity level, where would they be after school hours, sleep duration, travel time, study time and proximity to the school.

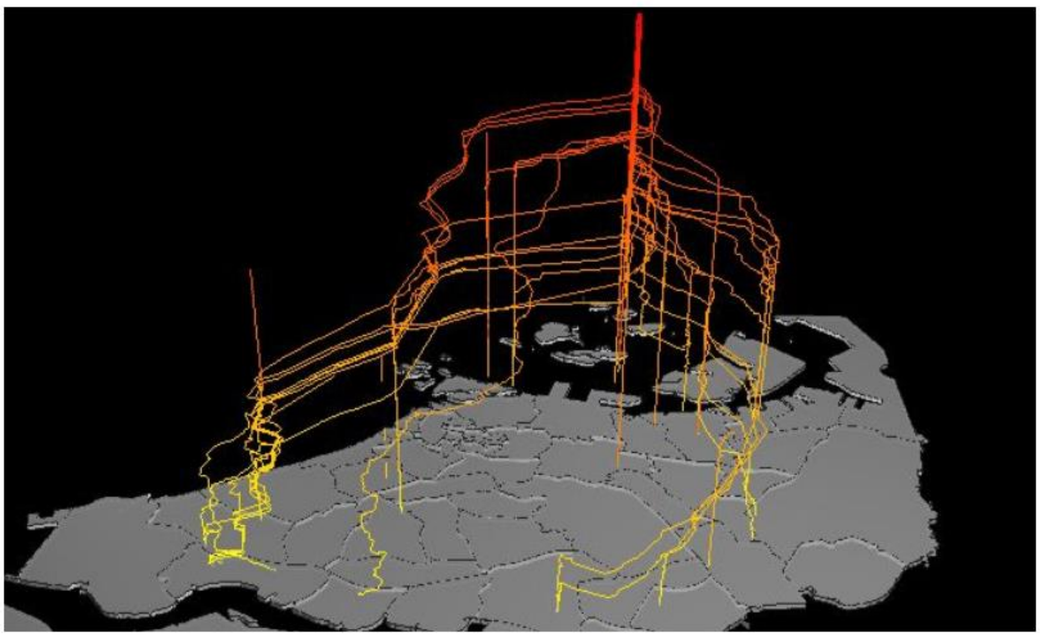


Figure 12: Space time cube describing the travel duration to schools for all the students.

The above visualization depicts the footprints of all students between 6am and 8am with respect to time, where the lowest point is at t="6:00:00" and the highest point is at t="8:00:00". A linear colour gradient from yellow (6am) to red (8am) is included as a visual aid.

Figure 13: Heat map of student activities after school hours

Largely the experiments echoed the facts published in the popular newspaper as the students on an average were found to sleep an hour less than wat is considered optimal. The research also had observations on the study time available to the students. The Teams quantified the correlation between travel duration and study time and noted the study time to drastically reduce with increase in travel durations.

2. Effects of transport and AC on carbon footprint.

Carbon footprint, commonly defined as the total amount of greenhouse gases produced directly or indirectly from human activities, usually expressed in equivalent tons of carbon dioxide. Greenhouse gases, if released in large amounts to the atmosphere, will result in a greenhouse warming effect that will negatively impact our climate and even increase the probability of natural disasters. In the past the teams have looked into the students' carbon footprint generated while commuting as well as exposure to from air-conditioned facilities during the experiments, and how they, as students, can help reduce this amount in conjunction with efforts made by the Singapore government to reduce the nation's carbon footprint for a cleaner and greener Singapore.

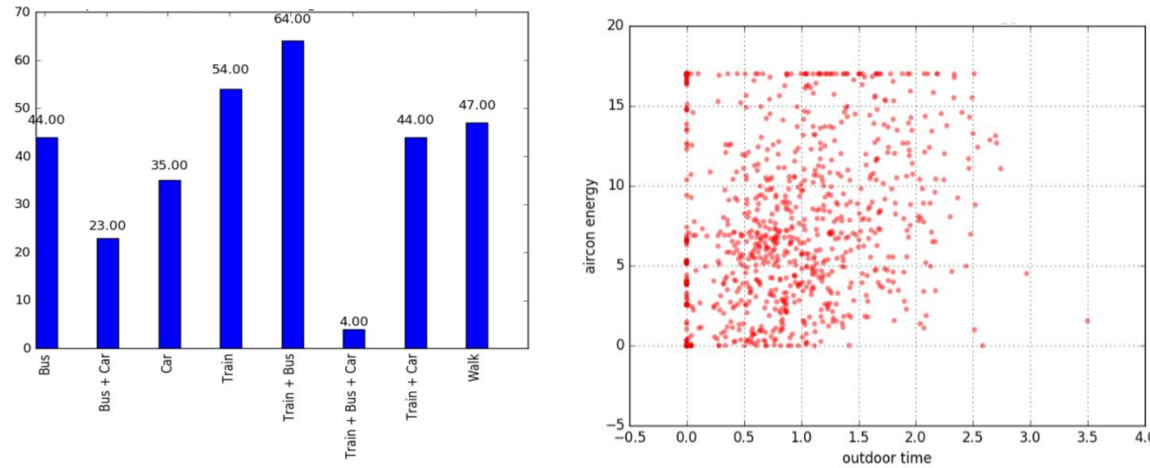


Figure 14: Visualizations describing the impact on carbon footprint

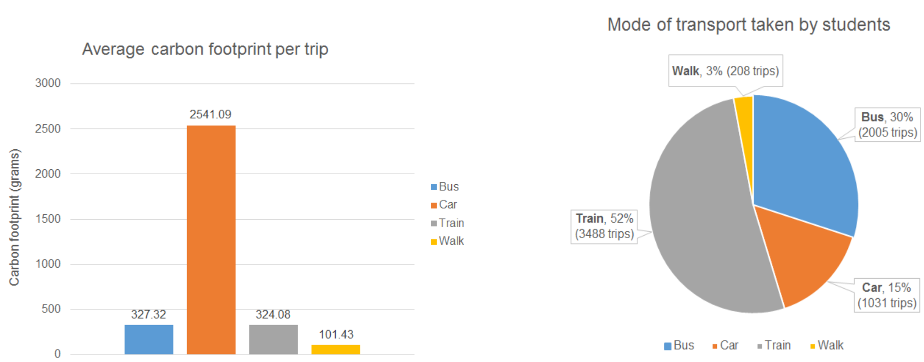


Figure 15: Transport modes used by students in Singapore and Outdoor time in relation to aircon energy

The investigation resulted in a set of recommendations on how students could help reduce carbon di oxide emissions with the support from various government agencies. For example, the group identified the fact that the private transport users have a higher impact on the nation's carbon footprint. As a counter measure, they suggested incentivized schemes such free bus / MRT rides for specified period to encourage more people to use benefit from public transport. The group also suggests methods to cut down on greenhouse emissions from the air conditioners. Usage of green construction methods like a green roof and educating the consumers on optimal usage / best practices while using AC were some of the suggestions.

3. What makes a student happy in Singapore?

The 14th Dalai Lama, a very well know Buddhist monk once said, *"A happy mind is a healthy mind, and a healthy mind is good for the body."* The above quote is the inspiration to our student group's investigation last year. The study attempts to understand what makes Singaporean students happy and explore opportunities of helping them to be happier.

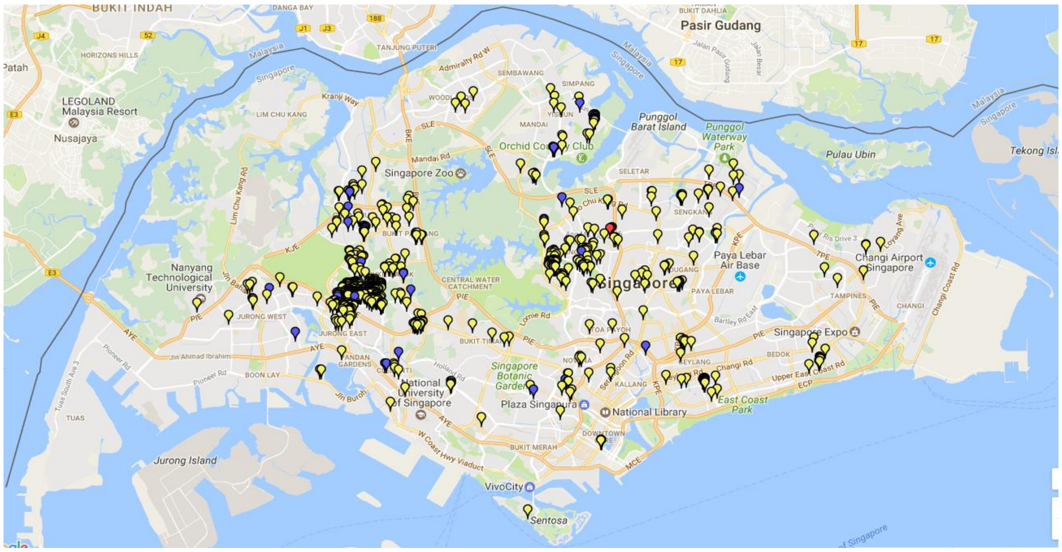


Figure 16: Happy Moments

The investigation explores the factors influencing the happy emotion in students in a given environment like a school or their residence. The factors considered were activities, locations and the physical environment parameters. It was found that the students were most happy during the first half of the day (8am to 2pm) and happiness is directly related to the activity levels. Research proved that students who engage even in the simplest form of exercise like walking or climbing stairs or spend more time in outdoors were happier than the rest. The group also identified specific zones in their surroundings and their physical parameters in the environment (temperature and noise levels) where students felt happy while they spent time with their friends.

Hence the study suggests introducing activities that allow students to be more active in outdoors so as to make them feel happier as well as lead a healthier lifestyle. At the schools have adequate free time in students' curriculum that allows them to take part in leisure activities which can help them destress.

Do’s and Don’ts

Do’s

1. Wear it on the move – whether you are indoors or outdoors, climbing stairs, travelling in a vehicle or walking.
2. Carry it around your neck using the provided lanyard, or clip it to your belt loop.
3. Charge the battery before it runs out, especially when you see the light blinking red.

Don’ts

1. Toggle on/off switch-Do not turn the off the device as they will be shipped to you in the ON state else you will risk missing your data.
2. Do not put it in your bag or pocket while on the move – this could affect the accuracy of the results.
3. Device is not water proof. Hence don’t submerge it in water, or wear it while bathing or get it wet when it rains.
4. Hit it against hard surfaces or throw it around, as it is a sensitive measuring device.
5. Lose the device. Keep it in a safe place when it is not in use.

Accuracy and Range of sensors

Sensor	Range	Accuracy	Units
Accelerometer	±2g~±16g	-	m/s^2
Gyroscope	±250 to ±2000	-	deg/sec
Magnetometer	±4800uT	-	uT
Light Intensity	0.165 to 100k	-	lux
Sound pressure	30 to 130	SNR: 63	dB
Relative Humidity	0-100	+/- 3	%
Amb.Temperature	-10 to +85	+/- 0.3 @ 25°C	°C
Pressure	300 to 1100 hPa	+/- 0.12 hPa	hPa
IR Temp	-40 to 125	+/- 3	°C

Table 4: Sensor details

Frequently Asked Questions

1. The SENSg device does not turn on, what do I do?

The sensors are designed to be 'low power' and do not light up very often. The chances are that the sensor is working perfectly. If you want to make sure, check that the switch is flipped towards the micro-USB charging port.

2. The LED on the SENSg device is blinking red, what do I do?

Flashing of red led indicates low battery levels. Hence the device needs to be charged immediately.

3. Something unexpected happened with the SENSg, what do I do?

Send an email to nse@science.edu.sg and let the SENSg team know. Include your name, contact information, and a description of what happened and screenshots or snapshots where applicable.

4. I dropped the SENSg device or it got wet, what do I do?

Write down exactly what happened at the back of this book. You won't be punished for accidents, but you can save a lot of time by letting us know.